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Supporting Collaboration in Problem-Solving Groups

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Abstract

Designing GSS that can be used effectively by co-located groups presents a number of specific problems that do not exist with other group configurations. In particular, any GSS in a co-located setting has an overhead of use that must be recouped by its benefits, or it reduces the overall group effectiveness. In distributed groups the same basic payback is necessary, but usually the GSS is also used as a communication medium; in co-located groups, members communicate directly so this immediate payback is not available to them and the benefit must come from the decision support strand of GSS.

The main contribution of this thesis is to provide a framework of collaboration that draws together the ideas from different models and theories of collaboration, which are also developed in this thesis. The purpose of this is to enable GSS designers for co-located work groups to observe and identify critical low-level incidents that enhance a group's effectiveness. From this point of view the thesis discusses how these models and method might be used in a GSS design process.

The framework of collaboration is used to describe 'collaborative schemata' at two levels. The first level uses 'concrete schemata' to describe individual instances of collaboration in a systematic, but flexible, manner. The second level uses 'abstract schemata' to draw out similarities between different instances of the same task, as well as different tasks. The purpose of concrete schemata is to capture real instances of collaboration, whereas the abstract schemata are developed from sets of concrete schemata to show a predicted generic type of collaboration. The relationship between concrete and abstract schemata is similar in a design context to that between user and design scenarios, where one represents real situations and the other is stylised to suggest a potential situation.

1 Introduction

Groupware Support Systems (GSS) can be categorised into two broad groups – those that support communication between group members (Group Communication Support Systems, or GCSS) and those that support decision making in groups (Group Decision Support Systems, or GDSS). Designing GSS that can be used effectively by co-located groups presents a number of specific problems that do not exist with other group configurations. The most difficult of these to overcome is that any GSS in a co-located setting always has an overhead of use that must be recouped and exceeded by its benefits, or else it reduces the overall group effectiveness. In virtual and distributed groups the same basic payback is necessary, but usually the GSS is also used as a communication medium; in co-located groups, members communicate directly so this immediate payback is not available to them and the benefit must come from the decision support strand of GSS.

Earlier work on human-computer interaction has made a strong distinction between whether the computer was being used either individually or collectively (Kammersgaard, 1988). In the collective context, the computer was seen as a tool to facilitate interaction. This has led to many groupware developments where the computer is the medium for some type of synchronous multi-user activity. GSS in co-located settings must have more clearly defined decision-support functions and display a broader range of interaction types. Arvola (2003) showed that human expectation of computer systems has developed to the extent that the nature of their interaction in a collaborative setting can change quickly in a session; one moment expecting the computer to act as a tool, the next expecting it to act as a medium.

Attaran and Attaran (2002) described the term ‘collaborative computing’ as being those products and services that foster collaboration. The purpose of this thesis is to add to the GSS designers’ toolkit a new framework of collaboration that allows them to understand group meetings in a structured way. This can help to inform them of the critical moments of low-level interaction for that group type. From this, the final part of the thesis looks forward to how this could be used practically by GSS designers to develop new technologies that foster collaboration in co-located settings.

The elusive ‘critical moments’ of interest are the moments where group members are able to bridge the gap between the individual and the group. When a group member achieves this they are introducing shared group knowledge that becomes the building blocks for group structures such as *group efficacy* (Bandura, 1977) and *group mental models* (Badke-Schaub et al., 2007). Both these constructs are difficult to extend from their individual-based equivalents. The extension from self-efficacy to group efficacy is problematic, because many other group dynamics influence a group’s behaviour. This prevents the measurement of group efficacy directly from the group’s members’ self-efficacy being straightforward. Bandura (1997) claims that group efficacy cannot be derived as a sum of personal efficacies, because of the influence of other group dynamics. Similarly, group mental models are more than a collection of individual mental models used in a group setting; they hold extra properties that synergise the individual models from which they are derived (Langan-Fox et al., 2004).

A meta-review of group models by Ilgen et al. (2005) describes how ‘structuring models’ – those that describe the development and maintenance of group norms, roles and interactions – have been dominated by the constructs of shared mental models and transactive memory. Shared mental models treat group knowledge as a group level construct, whereas the transitive memory perspective considers it to be a collection of individual perspectives, with a collective shared awareness. In this thesis an argument is made for how both perspectives can be used together to model complex task completion in groups.

The type of group that this thesis considers is that of co-located problem-solving work groups, with a particular focus on complex, unstructured problems. These are the type of problems that Rittel and Webber (1984) described as ‘wicked problems’ - those that are essentially unique or ill defined. A variety of problems are addressed in the different studies presented in this thesis, so that the idea of what represents a ‘complex’ task can be discussed and so that the generalisability of the developed framework can be shown over a range of different situations.

In the literature there are many contradicting definitions of a group. According to Adair (1986) this is because of the inherent generality of the word ‘group’, which requires further classification when it provides insufficient accuracy. Adair’s classification of ‘group types’ defines a *work group* as one whose members would have a common task or tasks, explicitly stated, upon which the group’s existence relies; such groups are typically temporary in nature and their leadership tends to be competency-based. This definition is used in this thesis to define the groups of interest, with one small modification – in this thesis a work group has a common goal, explicitly stated, upon which the group’s existence relies; the reason for this distinction is that the groups of interest, i.e. those addressing complex or unstructured tasks, will not be able to explicitly state their task when the group is created, because they will not understand it sufficiently well at that stage.

One way in which the development of group constructs can be observed is through the negotiation and adoption of group knowledge artefacts. Stahl (2006) suggests that knowledge can be viewed as a type of artefact in group work; however, viewing knowledge in this way presents some new challenges. For example, something physical like a mobile phone would generally be identified as a single artefact and two phones as two artefacts, but with intangibles such as knowledge it is harder to identify this boundary. It is also important to note that there is a hierarchical nature to knowledge, where some knowledge artefacts exist at a meta- or subordinate level to others, giving rise to knowledge artefacts that are organization knowledge structures.

Artefacts are usually adopted into a group through negotiation; a concept that has also been extended to include knowledge and information (Stahl and Herrmann, 1999). Olson and Olson (2001) saw this process as one of *clarification*, and split clarification activities according to whether the group was clarifying issues, goals or other activities. The negotiation process can lead to the adaptation of artefacts, as well as their adoption (Dourish, 2003), and this process leads to there being a difference between the artefact proposed by a individual and that which is finally used by the group. The nature of this adaptation depends upon the adaptability of the artefact; if a tangible artefact is not easily adaptable, a group can adapt their understanding of it instead, so that novel uses develop as group emergent knowledge.

Another characteristic of group artefact negotiation is that individuals tend towards optimal solutions for the problems that they are addressing, but the group tends towards solutions that fit Simon's (1957) idea of *satisficing*, i.e., solutions that are 'good enough' or 'fit for purpose' without necessarily being the best possible solution that the group could find if it gave infinite resources to the problem.

Pinelle et al. (2003), in defining the *mechanics of collaboration*, see collaboration as a set of interaction primitives that systematically represent both communication and cooperation. This definition looks at group interaction from the *functional* and *symbolic-interpretive* perspectives (Poole et al., 2004), but ignores deeper personal values; beyond the mechanics, lies the socio-cognitive nature of collaboration. Extending from this type of definition is the need to distinguish what sets collaboration apart from cooperation. When a person cooperates with another or others, they are willingly engaging in the same task or pursuing the same goal. However, there is no indication as to whether or not the cooperative person has any involvement in shaping the work process, defining potential goals or selecting a goal. Collaboration implies a much greater involvement in these areas and, therefore, needs to be evaluated from other perspectives. Collaboration also relies heavily upon coordination. A group is a complex system, comprising people and their interactions, which must be coordinated for them to perform and to display coherent group-level characteristics. Malone and Crowston (1994) suggest that cooperation, collaboration and competition can each be viewed as ways of managing dependencies between activities and, as such, are methods of coordination. This thesis reviews extant theory on collaboration and the related terms of coordination, cooperation and competition and proposes definitions that identify them both individually and in relation to each other.

It is always difficult to answer the question of 'what is an effective group?' or, more immediately, 'is this group being effective?'. In academic literature many measures have been proposed that depend on whether the focus for success is the immediate task in hand, the ongoing success of a group or the development of individuals within the group. In this thesis it is proposed that group effectiveness should be a broader metric than an immediate measure of group performance (Middup and Johnson, 2006) although providing an environment that enables the level of performance required is also very important. For example, in researching the decision-making capabilities of groups, Moore and Thomas

(1988) assert that ‘a distinction must be drawn between a good decision and a good outcome’ (p3). Group effectiveness should also include measurements of the group’s cohesiveness and whether completing a task together has increased the member’s ability and desire to collaborate again in the future (Halfhill et al, 2005).

1.1 Research Problem

The research problem that this thesis addresses is:

How can the design of support systems for collaboration in co-located problem-solving group meetings be improved?

The problem of providing support systems for co-located groups remains because any technology introduced into a group has a direct overhead of use that must be overcome with other benefits from the system. This thesis introduces a new way of looking at this problem, by showing an understanding of both individual collaborative instances and the generalisations that can be drawn from them and how these two perspectives can be used together.

1.2 Overview of Approach and Contributions

The main contribution of this thesis is to provide a framework of collaboration that draws together the ideas from different models and theories of collaboration, which are also developed in this thesis. The purpose of this is to enable GSS designers for co-located work groups to observe and identify critical low-level incidents that enhance a group’s effectiveness. From this point of view the thesis discusses how these models and method might be used in a GSS design process.

The diagram below (figure 1.1) provides an overview of how the models, theories and outcomes of studies are developed throughout the thesis to conclude with this framework. The framework is comprised of collaborative parameters and collaborative resources that represent the starting position for a given collaboration and a set of collaborative activities that represent the transitions through which the collaboration flows.

The framework of collaboration presented in this thesis is used to describe ‘collaborative schemata’ at two levels. The first level uses ‘concrete schemata’ to describe individual instances of collaboration in a systematic, but flexible, manner. The second level uses ‘abstract schemata’ to draw out similarities between different instances of the same task, as well as different tasks. The purpose of concrete schemata is to capture real instances of collaboration, whereas the abstract schemata are developed from sets of concrete schemata to show a predicted generic type of collaboration. The relationship between concrete and abstract schemata is similar in a design context to that between user and design scenarios, where one represents real situations and the other is stylised to suggest a potential situation.

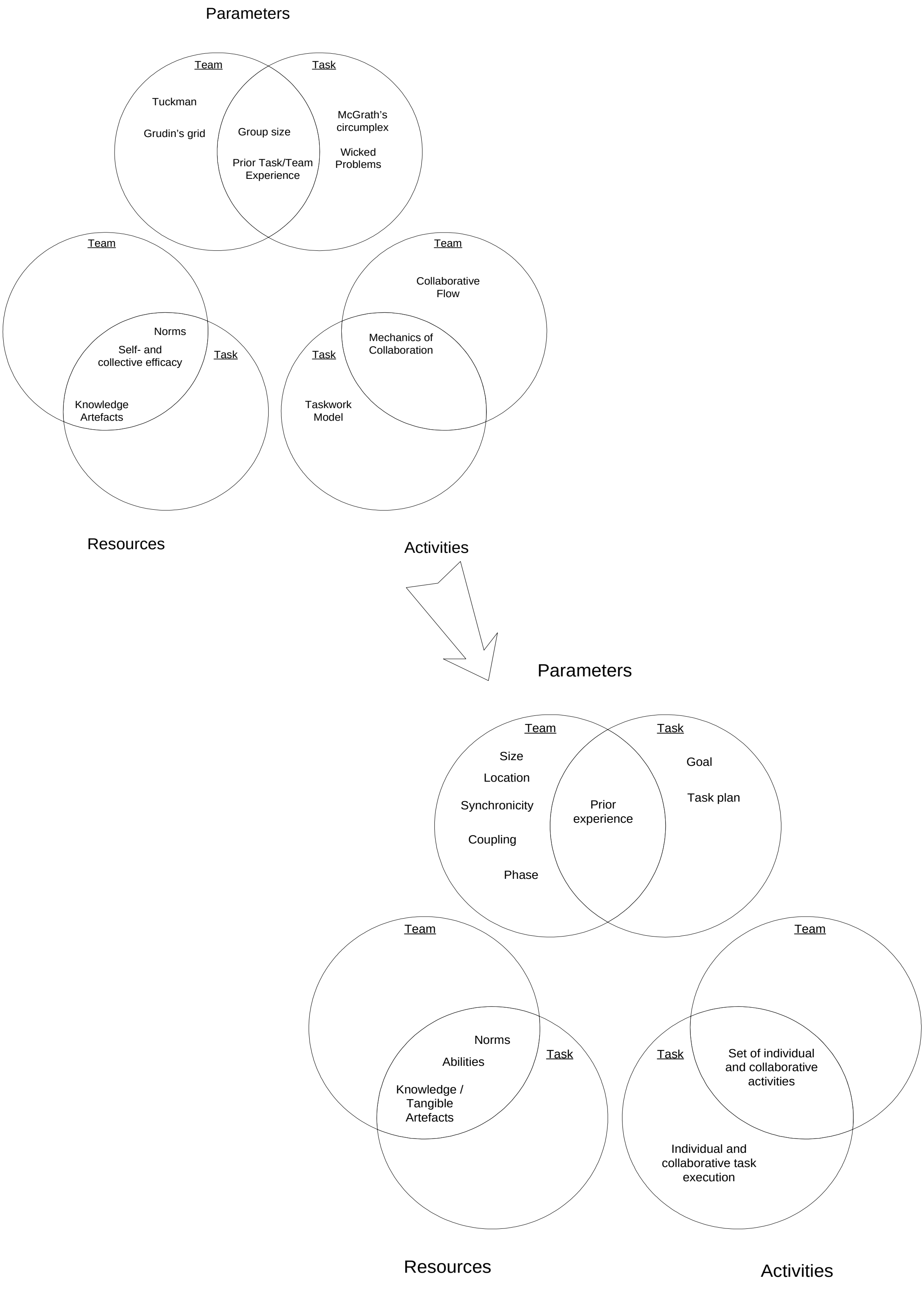

Figure 1.1. Transition of theories and studies into consolidated framework of collaboration

The collaborative schemata framework is developed in this thesis from the following contributions:

A theoretical contribution is made by reviewing the literature on knowledge and complex tasks and applying them to the adoption of group knowledge in collaborating groups. An understanding of the negotiation process required for the adoption of group knowledge is presented to support this theory.

The thesis contributes a taskwork model that shows how groups working in a number of identifiable states break down complex tasks; the transitions between these states are made through the process of these 'critical' collaborative incidents.

Following on from this, the thesis also contributes a conceptual analysis of collaborative flow, extended from the ideas of individual flow (Csikszentmihalyi, 1996) and group flow in creativity (Sawyer, 2003).

To evaluate both the taskwork model and the conceptual analysis of flow further, the research investigates how collaborative work is affected by disruptions in flow in the co-located meetings. Disruptions in flow in meetings can range from small disruptions, for example where there is an easily resolved misunderstanding between group members, to large disruptions, for example when a member of the group was absent from a previous meeting and is finding it difficult to follow the course of the one that they're attending. Flores et al. (1988) concluded that good design 'allows work to flow smoothly with a minimum of breakdowns in completing an action' and extending from that conclusion, this thesis asserts that GSS designers would benefit from understanding and reducing disruptions in flow as a type of breakdown.

Finally, the thesis draws together the contributions made by applying the theoretical contributions to another complex task. From this, reflections are made about the limitations and generalisability of the work presented here.

1.3 Description of Chapters

The thesis is organised into the following chapters.

Chapter 1: Introduction

This chapter is an introduction to the problem space, the main questions and the reasons for addressing this problem.

Chapter 2: People and Technology

Chapter 2 draws together literature from a number of disciplines to provide a comprehensive picture of how collaboration in small, problem-solving work groups has been previously represented. In particular, it draws from valuable management-related literature to extend the way in which small group work is discussed within the CSCW discipline.

Chapter 3: Understanding Group Constructs

Chapter 3 introduces a relatively small study, based upon groups of three people attempting a jigsaw puzzle. The work of Bandura (1977, 1997) is used to examine the problem of understanding group-emergent properties and how they relate to equivalent properties observed in individuals. The study is used to raise questions that are pursued throughout the rest of the thesis.

Chapter 4: Knowledge Artefacts and Complex Problems

Chapter 4 reviews existing literature on individual and group knowledge and the characteristics and challenges of complex problems. The key theoretical components are drawn from the development of the DIKW hierarchy (Ackoff, 1989; Zeleny, 1987), knowledge expressed as artefacts (Stahl, 2006) and the 'wicked' problems of Rittel and Webber (1984). The chapter goes on to draw together these theoretical strands to provide a theoretical basis by which knowledge artefacts can be used to express the way in which complex or unstructured problems are addressed by problem solving groups.

Chapter 5: A Taskwork Model

Chapter 5 reports on a study of two groups working on a complex problem over the period of four weeks. An empirical analysis is made of the co-located meetings of the study using SYMLOG (Bales and Cohen, 1979) to identify key 'activity focussed' moments in those meetings that were particularly relevant to the groups making progress in their task. This analysis is used to develop a taskwork model, which illustrates the states and transitions that problem solving groups work through in order to break down and complete complex or unstructured tasks.

Chapter 6: The Flow of Collaboration

Chapter 6 draws upon and extends the ideas of *flow* (Csikszentmihalyi, 1996) and *group flow* (Sawyer, 2003) to describe what it means for a group to be in collaborative flow. Examples from the earlier jigsaw and flora and fauna studies are used to illustrate the theory. Having established what it means for a group to attain flow in collaboration, the chapter also identifies the means by which disruptions in flow can occur and how these might be repaired.

Chapter 7: A Study of Flow

Chapter 7 introduces a study of flow at both task and activity level, where the effects of teamwork and taskwork are separated from each other by repeated trials of a relatively simple task, where the group members have prior experience of either their team, their task, neither or both. From this, both qualitative and quantitative analysis is made.

Chapter 8: Collaborative Schemata

Chapter 8 integrates the different threads of collaboration explored by the thesis into a framework of collaboration. The framework provides two tiers of collaborative schemata, allowing both individual instances and abstract collaborations to be defined in a comparable semi-structured form. The need for and purpose of an framework for this type of group work is established, and the card sort study, introduced in Chapter 7, is used with the theory and findings of the earlier chapters to develop this framework. The framework enables an observer to be able to express a particular collaborative instance in a way that can be compared with other instances in order to establish predictive abstractions.

Chapter 9: Lightweight Validation of the Framework

Chapter 9 introduces a final study that provides a new complex task, with which the collaborative schemata framework is reviewed and tested. The chapter also reflects on the other findings of the thesis, with respect to this new task.

Chapter 10: Conclusions

Chapter 10 reflects on the work presented in this thesis, including findings, limitations and potential for further research.

2 People and Technology

> If technology developers start from an understanding of human needs, they are more likely to accelerate evolutionary development of useful technology.
>
> from *Leonardo's Laptop*, Ben Schneiderman (2002, p76)

This chapter describes the type of groups of people that are relevant to the research in this thesis (and, by consequence, those that are outside its scope); it explains how, why and when these people come together as a group, and the things that they do when they are apart that are also significant to the group's effectiveness; finally, a discussion is made of how these people are supported by existing technology and the gaps that exist for further research.

Within the general research field of Human-Computer Interaction (HCI) there exists the sub-discipline of Computer-Supported Cooperative Work (CSCW), which amongst its interests considers groups or teams of humans and how they can be supported by technology. The work in this thesis is situated within CSCW; therefore in the first section of this chapter there is a review of the history of CSCW as a research area and an explanation of why this thesis is both relevant and a contribution to the field.

2.1 Computer-Supported Cooperative Work

According to Jonathan Grudin (1994b), the term Computer-Supported Cooperative Work (CSCW) was created in a workshop in 1984. The workshop, organized by Irene Greif of the Massachusetts Institute of Technology and Paul Cashman of Digital Equipment Corporation, drew together 20 people from different research fields, each with an interest in the role of technology in the work environment.

Grudin (1994a) says that it is important to adopt a workplace perspective rather than a technological perspective when developing groupware, but this can be difficult. The reason for this is that the designers producing groupware are fundamentally technologists and they are drawn into building systems because the technology exists to make it possible. The focus of CSCW was to understand the workplace better and, while still viewing it with a technological understanding, the purpose was to meet workplace needs with appropriate technologies rather than to find uses for technologies in the workplace.

The rich diversity of this initial gathering and subsequent contributors is one of the field's great strengths, but it is also perhaps its greatest challenge – as Grudin (1994b) calls it: 'the challenge of being multidisciplinary'. However, CSCW is still more focussed a research area than HCI, which is more interdisciplinary still.

Different research groups use the same terms to represent different things. Because of this, one of the multidisciplinary challenges of the CSCW community has been to develop mutually acceptable terms that give the community a precise lexicon with which they can work, even if this does not fit directly with the disciplines from whose work they are drawing.

For example, Grudin (1994b) defines the HCI *user* as ‘a person sitting at a display, entering information and commands and using the output’, whereas an Information Systems (IS) *user* is ‘the user of the output, a person who might not touch the keyboard’. These definitions are subtly different, yet they are still different and for people to be able to compare and discuss their work, they need reliable common terms. In this case, the solution was for the IS field to coin the term *end user* to identify the person at a terminal or keyboard.

Crabtree et al. (2005) explain that in more recent times there has been a shift away from workplace studies in CSCW, with more laboratory-based research entering the domain. This is possibly because as the research area has developed, questions that have been asked by the fieldwork researchers have been increasingly difficult to unpick in workplace situations. There is a need now for CSCW research to focus iteratively between the workplace, where real problems can be found and documented, and controlled research environments where clues to the solutions of these problems can be addressed in a more focussed way.

Ackerman (2000) states that the difficulty for CSCW researchers is that there is, and probably there will always remain, a gap between what is required socially and what it is possible to support technically. He says ‘exploring, understanding and hopefully ameliorating this social-technical gap is the central challenge for CSCW and one of the central problems for human-computer interaction’. He proposes that the existence of this challenge provides an opportunity to refocus CSCW as a main contributor in understanding the nature of this gap and in proposing workable, scientifically grounded solutions.

This thesis provides an empirical and theoretical contribution to the CSCW research area by developing, through a series of linked studies, a better understanding of collaboration. The purpose of this is that both the empirical results and models developed here can then be used in fieldwork to improve the performance of co-located problem-solving work groups.

2.2 Groups

There are many contradicting definitions of a group. According to Adair (1986) this is because of the inherent generality of the word ‘group’, which requires further classification when it provides insufficient accuracy. In early CSCW research, Bannon and Schmidt (1989) noted, “The term ‘group’ is quite blurred and is often used to designate any kind of social action”, but that in general a group is “a relatively closed and fixed ensemble of people sharing the same ‘goal’ and engaged in incessant and direct communication”; they go on to add that the term ‘goal’ is equally blurred, with its meaning changing according to context and author.

Forsyth (1999) points out that groups are not all benefit without cost. There is a workload overhead to develop and maintain a group, which must be considered as an offset against the benefit of sharing a task. In this thesis the activities required to develop and maintain a group are called *teamwork activities* and the activities required to address the goals of the group *taskwork activities*. Johnson et al. (2003) noted that because teamwork activities – the group-level tasks that sustain and maintain a group through collaboration – introduce their own overheads, they need to be considered along with taskwork activities when trying to understand collaborative group work. Lim and Benbasat (1991) claim that the content of messages between members of a work group can be categorised as *task-oriented* or *social-emotional* – a distinction that supports the existence of separate taskwork and teamwork activities. In the literature, opinion varies as to whether communication acts all carry a mixture of both these types of content or not; for example, Bales (1950) describes all messages in terms of being one category or the other, whereas McGrath (1984) suggests that all communication acts carry both to a greater or lesser degree. This is investigated in depth in this thesis, as understanding the speech acts is important to separating out the taskwork and teamwork activities.

Poole et al. (2004) have identified nine theoretical perspectives from which small groups have been examined in a meta-review of a wide selection of academic literature; each is described here in Table 2.1. Each of the perspectives can create a different focus for the analysis of group work, and therefore it is helpful to situate new studies within this categorisation in order to support the intention of the study. The thesis will draw upon these descriptions later to describe the focus of the subsequent studies.

Table 2.1. Interdisciplinary Perspectives on Small Groups, from Poole et al. (2004)

Perspective	**Focus**
Psychodynamic	Groups are examined to understand their behaviours that lie beneath the surface, in terms of deep psychological or socio-psychological dynamics.
Functional	Groups are examined in terms of inputs and processes whose functions influence group effectiveness.
Temporal	Groups are examined to better understand how they develop and change over time.
Conflict-power-status	Groups are examined in terms of power, status, resources and social relationships. The group structures associated with these dynamics are also examined.
Symbolic-interpretive	The social construction of the group is examined, with an effort to understand the internal notions of 'meaning' that a group constructs. Social interaction, language, symbols and the interpretations of both individuals and groups are elements of this type of research.
Social identity	Groups are examined in terms of their members' social identity and how these identities are constructed, as well as the interactions between different social identities.
Social-evolutionary	This is a research school that considers the group structures and dynamics adopted to be influenced by evolution. Therefore, in social-evolutionary terms, group members choose structures and ways of interacting that naturally fit with the long-term evolution of mankind.
Social network	Groups are examined as elements of larger social networks.
Feminist	Groups are examined for gender biases that stem from the enactment of power and privilege that favours one gender over the other.

2.2.1 Work groups

The type of group considered in this thesis would be described by Adair as a *work group*, whose members would have a common task or tasks, explicitly stated, upon which the group's existence relies. Such groups are typically temporary in nature and their leadership tends to be competency-based. The presence of a common task or tasks amongst group members does not automatically imply that they also share a common goal.

Work groups have been selected because their access to technology, at least in a significant number of cases, will be greater than average. This and the make-up of the groups being task-related make them an appropriate candidate for study.

There has also been much discussion as to whether the terms *work team* and *work group* can be used interchangeably. Adair (1986) cautions that one should neither assume that all work groups are teams nor assume that all tasks need teamwork. However, Sundstrom et al. (2000) counter this by claiming that there has been no consistency in the distinctions made between the terms. The concept of team is that there is a joint task that requires cooperation between a group of people (Argyle, 1991), so it is reasonable to consider any group that is fundamentally *purposive* (Poole et al., 2004) must implicitly be a team. In this thesis the term *work group* will be used to describe the groups in the study.

Adair's (1986) study of work groups also identified that a number of characteristics help a work group to be more cohesive. These are: that the members share physical proximity; that they share the same, or similar, work; that the group displays homogeneity; that the personalities of the group's members do not clash; that there is effective communication between the group's members and that the group's size is not too large.

It is worthwhile considering each of these characteristics in turn, as a review of how work groups and work practices have changed since the mid-1980s and as a check for their ongoing relevance.

A work group needs physical proximity. It may still be true that close physical proximity aids the cohesion of work groups, at least until the group has hit the *norming* phase of Tuckman's (1965) development sequence; Tuckman's theory is described in detail in section 2.3 of this chapter. The reality of the modern workplace, though, dictates that a group's members are often physically dispersed; virtual organisations and virtual work groups exist where the members' contact is all through electronic means, despite contributing to the same tasks and goals (Sundstrom et al., 2000). Bos et al. (2006) have also suggested that group members can suffer 'collocation blindness' when in partially distributed groups, thereby favouring collaboration with co-located participants.

A work group should share the same or similar work. In accepting that a work group is identical to a work team (Sundstrom et al., 2000), this characteristic holds true in terms of a possessing a shared goal or purpose. How valid this turns out to be will be determined by the complexity of the task – greater complexity will lead to more specialisation being needed to progress towards the goal.

Personalities of work group members should not clash. This is often seen as the key to high performing work groups. To achieve this harmony two things are required; firstly, the group members should have complementary characteristics (Belbin, 1981; Halfhill et al.,

2005) and secondly, they require the time together to develop into a *performing* unit (Tuckman, 1965). The longer the life-span of a team, the more important it becomes that there is personal compatibility between the team members, but this may be particular to where they have to share the same physical workspace (Sundstrom et al., 2000).

A work group should display homogeneity. In this case, by homogeneity Adair means that the group members should have similar stature, background, ideas, etc. To an extent, this is a characteristic that contradicts the previous one. There is little point in a work group having identical traits, if the purpose of the group is to achieve a 'greater than the sum of the parts' effect through complementary skills and competencies. Taking the studies presented in this thesis, it finds that groups performing trivial or repetitive tasks may get away with homogeneity of members, but a group involved in problem solving should maximise its assets through well-selected diversity.

This is supported by Bowers et al. (2000) who, in a meta-analysis of studies on group homogeneity concluded that complex tasks in general require higher levels of creativity to be successful and that group heterogeneity offers a greater opportunity for effective creativity. Oliver and Maxwell (1988) suggest that heterogeneous groups can also be effective with fewer contributors, thereby requiring fewer members, because of the diversity that they can draw upon.

One personality characteristic that appears to positively influence a group, when homogeneous, is the cognitive style of the group's members. Priola et al. (2004) showed that a mix of intuitive and analytic cognitive styles in a group led to polarisation, rather than complementing each other, whereas homogeneous groups of the two styles were much more harmonious.

The external display (i.e., how they appear to outsiders) of a work group is important. Goffman (1969) describes how one of the major characteristics of being a team is looking like one. Collaboration, in Goffman's terms, is about providing a united front for a *performance*, i.e., interaction with those external to the group. Different opinions should only be expressed when the group is alone.

An interesting further issue on the subject of group heterogeneity is made by Barker et al. (2000), who point out that with a combination of increasing mobility and virtual collaborative environments the heterogeneity of groups is inevitably increasing and therefore becomes more of an issue of management, rather than one of choice.

A work group needs effective communication between its members. The more highly-coupled the individual roles of the team members in the performance of their task, the more necessary it will be for effective *direct* communication between members. If their roles are more distinct, however, then the effectiveness of communication to and from the team leader will be more important.

Effective communication at the group's boundaries is also important in avoiding *groupthink* – the phenomenon where a group can convince itself that an erroneous decision is correct, or vice versa – by becoming too close to the problem and losing its understanding of the bigger picture (Janis, 1982). Groups typically display polarisation behaviour (Pescosolido, 2001), where they polarise towards risky or conservative behaviour regardless of their individual natures.

A work group should not have too many members. Handy (1985) points out that the more members a group has, the greater the diversity of knowledge, skills and talent it will have available. However, with each member added to the group, there is an increased likelihood that individual assets will not be utilised.

Also, as the size of a group increases there is a tendency for the group's efficiency to drop when it is measured against the sum of each individual's efficiency. This has come to be called the *Ringlemann effect* (Ingham et al, 1974; Kravitz and Martin, 1986). The name refers to Maximillian Ringlemann, a French engineer who, around the start of the 20th century observed that in a tug-of-war, the pulling force of eight people was only two-and-a-half times that of an individual's contribution. The *Ringlemann effect* however, more generally refers to any production losses in groups as a combined result of social loafing and coordination losses. These phenomena are discussed in more depth in Chapter 6, where the detail of the problems of sub-optimality in groups is unpacked.

Some theorists suggest that the optimal size for a group is between five and seven members (Handy, 1985); others prefer to state that it is the smallest number required to complete the task (Sundstrom et al., 2000). However, if the task is novel, unstructured or complex – i.e. the majority of non-trivial tasks – then it is not possible to determine at the outset what the smallest number of required contributors is.

Another issue with Sundstrom et al.'s (2000) assertion is that the skills and capabilities of the group members, with respect to the task they are undertaking, may affect the number of them needed to perform the task effectively. Two skilled people may perform a task as well as six less capable ones in certain circumstances.

The appropriate size for a group is related to the task it is expected to perform. In general, however, it is assumed that the minimum number required to form a group is three people (Fjermestad and Hiltz, 1999), although some writers (e.g. McGrath (1984); Brown (1988)) believe that as few as two people with some element of interdependence constitute a group. The studies presented in this thesis focus upon groups of between three and six people; the reason for this focus is that this represents the most commonly accepted range that represents a 'small' group. In the final chapter consideration is given to how generalisable this is in terms of larger and smaller groups.

2.2.2 Problem-solving Groups

All groups have problems to solve: as has already been discussed, they need to solve (or resolve) all the problems that prevent them from working together as effectively as possible, such as developing shared norms and common ground. However, the term *problem-solving groups* in the thesis refers to a particular type of group; this type of group has a complex or unstructured problem as its main task and the primary or sole reason for its members to work together is to solve that problem.

2.2.3 Group Development

A group's members establish rules for mutually acceptable patterns of behaviour that are accepted as norms during the development of the group. Some norms are established immediately, as each group member joins with a behavioural framework that overlaps in some way with the framework of other group members. Other norms are established through the process of *storming* (Tuckman, 1965), where group members challenge each other's personal norms to establish mutually acceptable norms for the group.

Tuckman's theory of forming, storming, norming and performing (Tuckman, 1965), with a fifth and final phase - adjourning – added later (Tuckman and Jensen, 1977), provides a well used but slightly formulaic framework for showing the phases that any group must go through to become effective (see Table 2.2). In particular, it illustrates how group norms, which will ultimately define the group's effectiveness, are generated. The theory has been extended where later researchers have pointed out that norm formation and revision is ongoing throughout the lifecycle of the group (Graham, 2003), leading to alternative models of norm development.

Table 2.2. Description of Tuckman's theory

Group Phase	**Description**
Forming	The group forms as the members orient themselves by testing the boundaries of expected interpersonal behaviour and of what they perceive to be the tasks expected of them. At the same time, they are looking to establish the relationships with other group members and to identify suitable norms of behaviour drawn from previous experience. The forming stage exists whilst group members attempt to establish an understanding of their level of common ground without conflict.
Storming	At some point the level of common ground is insufficient for the group's ongoing development and it enters the second phase – storming; this phase is "characterized by conflict and polarization around interpersonal issues" (Tuckman, 1965). To develop further common ground, group members now need to change and the conflict arises as a result of individual resistances to change. Conflict may also arise as a result of resistance to the task requirements.
Norming	This is the phase in which resistances are overcome, and the group members develop new norms of behaviour and new roles that are both suitable for the inter-relational dynamics of the group, as well as for the tasks that the group has been created to undertake. The norming phase results in strong group cohesion and a sense of shared identity amongst its members.
Performing	The final operating phase in Tuckman's model identifies the point at which the group's identity, norms and members' interpersonal relationships are so well defined and mutually acceptable within the group that the group's overall structure becomes a tool that effectively serves the group's tasks.
Adjourning	The fifth stage – adjourning – was added some twelve years after the original four-phase model was proposed. The reason for adding this was to have a way of describing how groups break up; another common term in the literature for this phase is 'mourning'. The way in which a group breaks up affects what the individual members take away from it, in terms of what they believe were effective norms, roles and strategies. Consequently, this is the baggage that they take into the next group they join and directly influences the early phases of that group's development.

In 1990, Kraemer and Pinsonneault commented that more research was needed on the stages of group development and how they affect the impact of Groupware Support Systems (GSS) on groups. Since that time the CSCW community have completed many workplace-based studies that implicitly deal with particular phases of group development as can be understood from Tuckman's theory (e.g. Heath and Luff's (1991) study of the London Underground is of a performing group), but there has been little reflection on how a group's transition between phases affects its use of GSS.

Some norms are enforced more strongly than others and some are not enforced for all group members. For example, norms regulating the behaviour that directly relates to the group goals are more strongly enforced than are other norms (Krech and Crutchfield, 1962).

The following diagram (figure 2.1) is a representation to show that Tuckman's theory is still a valid way for describing the developmental process that a work group goes through in order to be effective, but also showing how the shared norms brought to the group by its members are negotiated before being extended to the set available to the group when it can be said to be 'performing'. The diagram also shows that when the group breaks up, each member takes away a modified set of norms that they would introduce as a member of future groups.

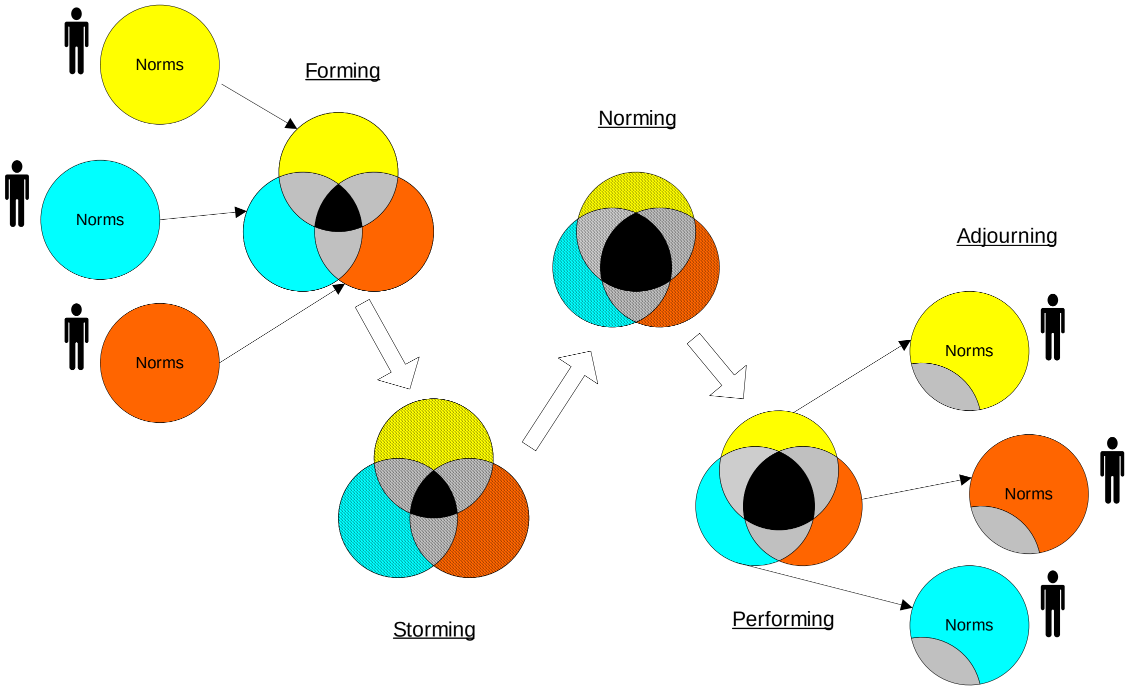

Figure 2.1. The effect of Tuckman's group development phases upon individual norms

The norms established will be different for every group, and within the group will vary for every problem. However, the process of establishing norms through conflict and negotiation remains essentially the same: a group member does something that another group member deems to be inappropriate, in a situation where the group have no previously-agreed norm of behaviour; then the group members need to negotiate to decide whether that action is appropriate or not, and define a mutually-acceptable way of working through that situation, or similar ones, in the future. Furthermore, a group that can quickly establish norms to which all the group members subscribe is in a better position to perform effectively than one that is still trying to establish effective norms. Some definitions of group norms state that they don't need to be enforced across all the members of the group (e.g. Schultz, 1989), however these seem to be individual norms within the group rather than the norms of the group. Identifying this process presents a number of problems that need to be addressed. Primarily, norms are only apparent to an external observer if they are either explicitly negotiated or if non-compliance is enforced in some way. This means that the presence or absence of some shared norms may not be observable if the group are so well matched that the storming phase does not take place.

If the group members often split into sub-groups and these sub-groups consistently comprise the same people, then it is also possible that those sub-groups will have their own norms that may be extensions or variants of the main group norms. Sub-groups are likely to rely on fewer norms, or at least have fewer observable deviances, as there are fewer different personalities over which to maintain normative behaviour.

In this thesis a group norm is defined as a *mutually acceptable mode of repeatable behaviour that all members of the group conform to and that draws censorship from other group members for non-compliance*.

2.3 Tasks

This section is a review and comparison of literature relating to tasks and provides the working definitions for *goal*, *task*, *sub-task* and *activity* required by the thesis; these are all inter-related terms that are used with a variety of meanings, according to author and context and therefore require a precise definition to support the arguments presented in this work.

2.3.1 What is a group task?

In academic literature a number of terms, such as task and activity, are used to describe the things that members of groups do as a function of that membership. These terms have been ascribed a variety of meanings by their authors, some of which are inconsistent or overlapping.

For the purposes of this thesis a group task is defined as *a description of the work required to achieve the overarching purpose(s) for the group's existence*.

When a group is created to undertake a task, it is not likely that the description of the work required is very clear; often it will merely be a high-level task. One of the problems that the group must address is how to understand the task and how to break it down into achievable activities. Within the scope of the main task, sub-tasks can be identified that represent the work required to achieve a definable milestone towards the completion of the main task. Within each sub-task, activities can be identified that represent fully defined pieces of work with known information and resources that result in the achievement of a specified goal.

2.3.2 Types of Activity

McGrath (1984) developed what he called a 'group task circumplex' (see figure 2.2) – a way of categorising group activities (his use of the word 'task' more accurately matches the use of the word 'activity' in this thesis). Forsyth (1999, p10) describes the circumplex as a model that identifies eight basic activities undertaken by groups: planning, creating, solving problems, making decisions, forming judgements, resolving conflicts, competing and performing. The model was validated empirically by Straus (1999).

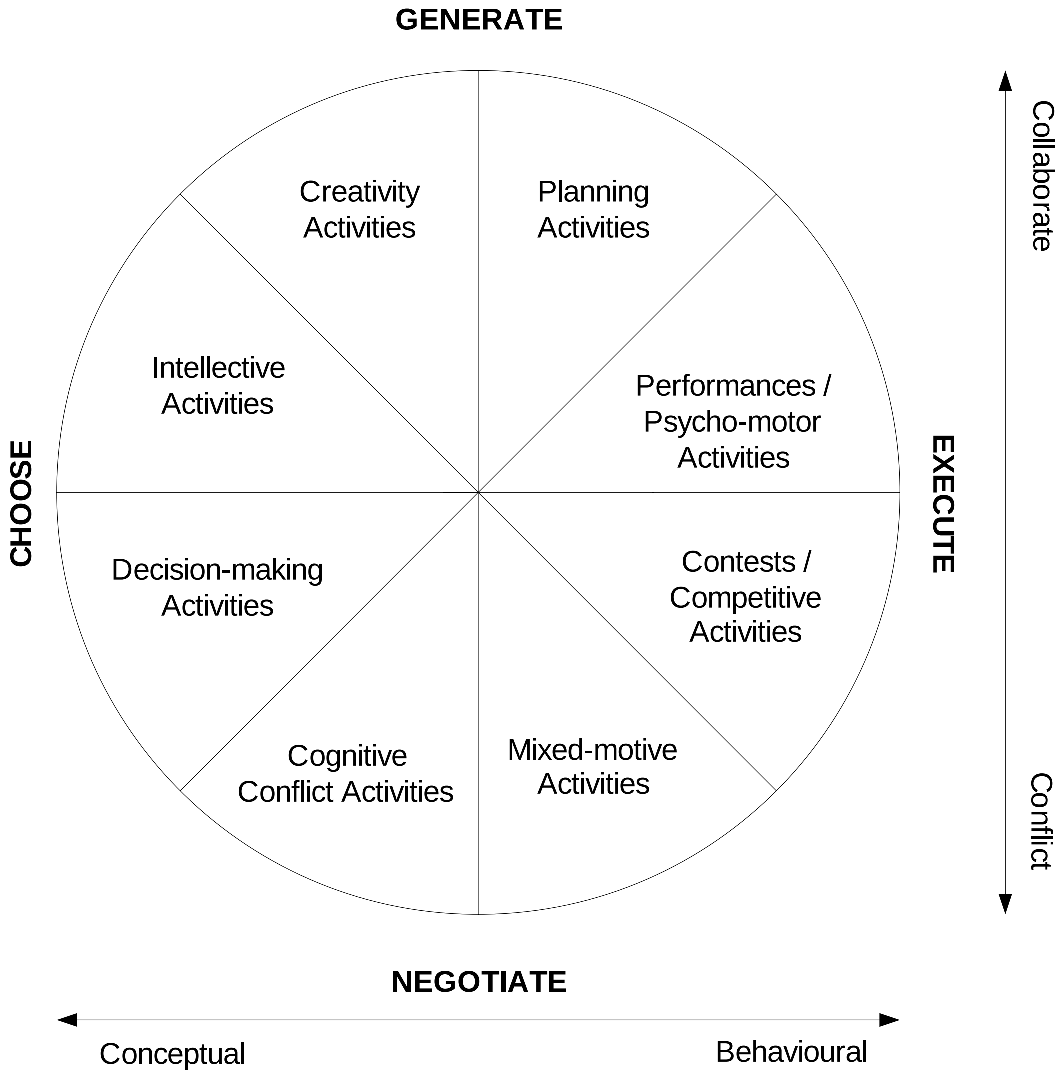

Figure 2.2. McGrath's Group Task Circumplex, adapted from McGrath (1984).

McGrath's model makes a number of interesting sub-divisions of his eight basic activity types; the first of these is the four quadrants that are labelled generate, choose, execute and negotiate. When groups perform *generate* activities they are developing further activities by either making creative steps towards completing their main task or planning how to execute already created activities. When groups undertake activities that *choose* approaches to their task they either perform intellective activities that develop approaches to fully-understood tasks, or they perform decision-making activities that develop approaches to more complex tasks, where possibly both the task and goal are not yet fully understood. When groups *execute* activities, the execution of the task may be harmonious (these are the performances or psycho-motor activities in the diagram, but should also be taken to include non-physical tasks such as problem-solving) or there may be conflict, where the activity represents some sort of contest or competition between its participants.

The final quadrant, that represents when the activity is *negotiation*, can also be split into two; when this negotiation regards the decisions of the group, then this is termed a cognitive conflict, and when it is a dispute over issues of competition, then it is termed a mixed-motive activity (the mixed motives being a desire to both compete and cooperate at the same time).

A second split in McGrath's categories is between the conceptual and the behavioural. This tries to capture the difference between activities where group members try to work out how to achieve their task, and/or meet their goal, and activities where they are in some way actively working towards that outcome.

A third split in the categories is the distinction between those activities where the group members are collaborating (or cooperating, or coordinating – a distinction that is discussed later in this chapter) and activities where the group members are in some sort of direct conflict.

2.3.3 Grouping Activities

Wild et al. (2003) suggested that there are four candidate strategies for grouping activities so that they can be undertaken as efficient sub-sets of all the work that a person has identified. Theirs is a description of strategies for the individual, but considered here is what these strategic groupings could mean for work groups. The four strategies are:

Grouping by deadline. The deadlines that apply for group members trying to complete sub-tasks for the group may be either internally set or externally. Generally, on an ongoing basis, they will be negotiated internally by the group; the only externally set deadlines will be for sub-tasks that are critical to reporting milestones or to completion of the main task.

Grouping by location. This is a particularly valuable grouping to consider when looking at scheduling a group's work to its members: not only might an individual choose to group a number of sub-tasks to a location for expediency, a group might also choose to schedule a certain sub-set of activities to one individual because they all depend upon a particular location.

Grouping by participant. This grouping could be dependent upon the two previous ones, in that activities are grouped to take place in a particular location at a particular time, because that coincides with the availability of a third party participant. Alternatively, it might be independent of those.

Grouping by role. Wild et al (ibid) were referring to one of many imposed or self-selected roles that an individual might take throughout a day, which leads to them grouping a number of activities under the umbrella of that role. From a group perspective the same can apply, ie, a group role, either imposed or self-selected, might lead an individual to negotiate with the group that activities related to their role be scheduled to them.

These candidate strategies go some way to explaining how a person can effectively complete small, well-structured activities efficiently. However, with complex tasks this efficiency is offset by how well and how much of the task is understood at any given time.

Another issue to consider is how clean are the applications of these task grouping strategies once a person has to work in a cooperative or collaborative environment. In Chapter 3, the general problem of how to apply individual measures in a group context is addressed.

2.3.4 Task Complexity

The simplest tasks a group might have to complete could be termed *trivial* or *routine*. A trivial task would be one that is so simple that it could be completed just as effectively by an individual and the presence of other group members at best over-resources the problem and at worst introduces an overhead. Routine tasks would be ones that the group has completed previously *as a group*, so no new intuitive steps are required. In this thesis these categories of task are ignored, as the group interaction during the progress towards complex task completion is the area that the research focuses upon.

Other tasks, where a group has to perform at least some intuitive steps to define taskwork or teamwork activities in order to complete the task, can be considered to exist on a continuum according to their complexity.

According to Wood and Atkins (2000), complex tasks are distinguishable from simple tasks when they have the three following criteria:

i. Cognitive effort is the critical determinant, rather than physical effort;

ii. The relationship between effort and performance is difficult to discern; and

iii. Effective performance will require problem solving until the task is well learnt.

For problem-solving groups undertaking complex tasks, one of the main problems that they need to work through is that the problem is not only complex, but initially it is also ill structured. An ill-structured task is one where the steps to completion are not obvious, whereas a task that is merely complex might be difficult to work through, but the path through that work has a well defined structure.

Another possible characteristic of an ill-structured task is that the goal of the task is not clear. In many complex tasks, e.g. design tasks, the goal can be quite vague or exist at only a very high level, and it is the process of working through the task that actually modifies or adds definition to the purpose of the task itself.

The problem of task complexity is investigated in depth in Chapter 4, where it is related to the generation and availability of knowledge within a group.

2.4 The ‘Cs’ of CSCW

In briefly discussing the extant CSCW research, it has been noted that in more recent times the second ‘C’, which was originally taken to abbreviate the word *cooperative*, has with increasing regularity been cited as *collaborative* instead. The two words are not synonyms, yet they are being used interchangeably in a research discipline that prides itself on its precise definition and use of terminology.

In this section the literature that makes use of these terms, and two other related ‘Cs’ – *coordination* and *competition*, are reviewed; the similarities and differences, both within and outside the CSCW community, are identified and definitions that relate to the work of this thesis are proposed.

Schmidt and Bannon (1992) say that cooperative work “should be taken as the general and neutral designation of multiple persons working together to produce a product or service” (p9). This illustrates the difficulties in early CSCW literature in distinguishing between cooperation and collaboration. The Schmidt and Bannon definition takes no account of the idea that cooperation may exist between parties without a shared goal.

Leinonen et al. (2005), in a qualitative study of a globally distributed team, found that to achieve collaboration the team members had to pass through three levels of awareness. First, they had to be aware of the *possibility* of collaboration. If they were aware that collaboration was possible, then second they had to gain an awareness of the *aims* of collaboration. Once they were able to identify the aims, the third level of awareness that they needed to acquire was an awareness of the *process* of collaboration. Only once they were aware of all three things were they in a position to collaborate.

Malone and Crowston (1994) suggest that cooperation, collaboration and competition can each be viewed as ways of managing dependencies between activities and, as such, are methods of coordination. In defining coordination this way, they identified four types of coordination that people working together needed to manage and they suggested that different systems were needed for the support of processes that represented these four types of coordination (see table 2.3). An interesting point of note is that they saw *group decision making* and *communication* as two further processes outside the scope of the four types of coordination identified; this thesis sees all the processes as important components of collaboration in complex tasks, which are aspects of the decision-making process, rather than alternatives to it.

Table 2.3. Processes for coordination, from Malone and Crowston (1994)

Process	Description
Managing shared resources	This process reflects task assignment and prioritisation, where the shared resources include the human resources of the group. This thesis extends the management of shared resources to include the process of shaping exactly what those resources are in a group context.
Managing producer / consumer relationships	This process represents the identification and management of sequencing prerequisites, so that activities that require a certain input (consumer activities) are adequately supplied by those activities whose output is consumed (producer activities).
Managing simultaneity constraints	This process represents the management of activities that relate to each other in some way and can be completed in parallel.
Managing task / subtask relationships	This is the process of goal decomposition, where smaller, more specific sub-goals are identified from an initial single goal.

Lim and Benbasat (1991) define collaboration as a more general term than cooperation, where collaboration can also include competition and negotiation. This thesis describes how negotiation is an important aspect of collaborative work (see Chapter 4), but disagrees that this includes competition. One reason for the difference in these distinctions is, perhaps, that Lim and Benbasat (ibid) see collaboration as the 'application of individual effort by two or more persons in a joint task', whereas this thesis would describe that as cooperation.

One of the reasons that different authors have used overlapping terminology to describe the same types of event is that sometimes they are looking at different granularities of an event. For example, a group of people may have a clear reason to collaborate (i.e., they have an obvious shared goal and can see a way of working closely together to achieve it). However, it is still unlikely that every activity they then undertake can be termed collaboration in the same way. Within their pursuit of the overall collaborative goal, they may identify activities that require a looser coupling, or that have a less obvious shared sub-goal. Sometimes problem-solving groups will even manage an element of controlled competition.

The definitions that are used in this thesis relate to the type of interaction required by a group so that they can work together towards their main goal.

The diagram (figure 2.3) represents a view of the 'C's of collaboration, cooperation, coordination and competition (along with awareness) in relation to each other. The two axes represent the level to which group members can be said to have shared goals and the strength by which their work is coupled – i.e., the amount that their activities are interdependent to each other.

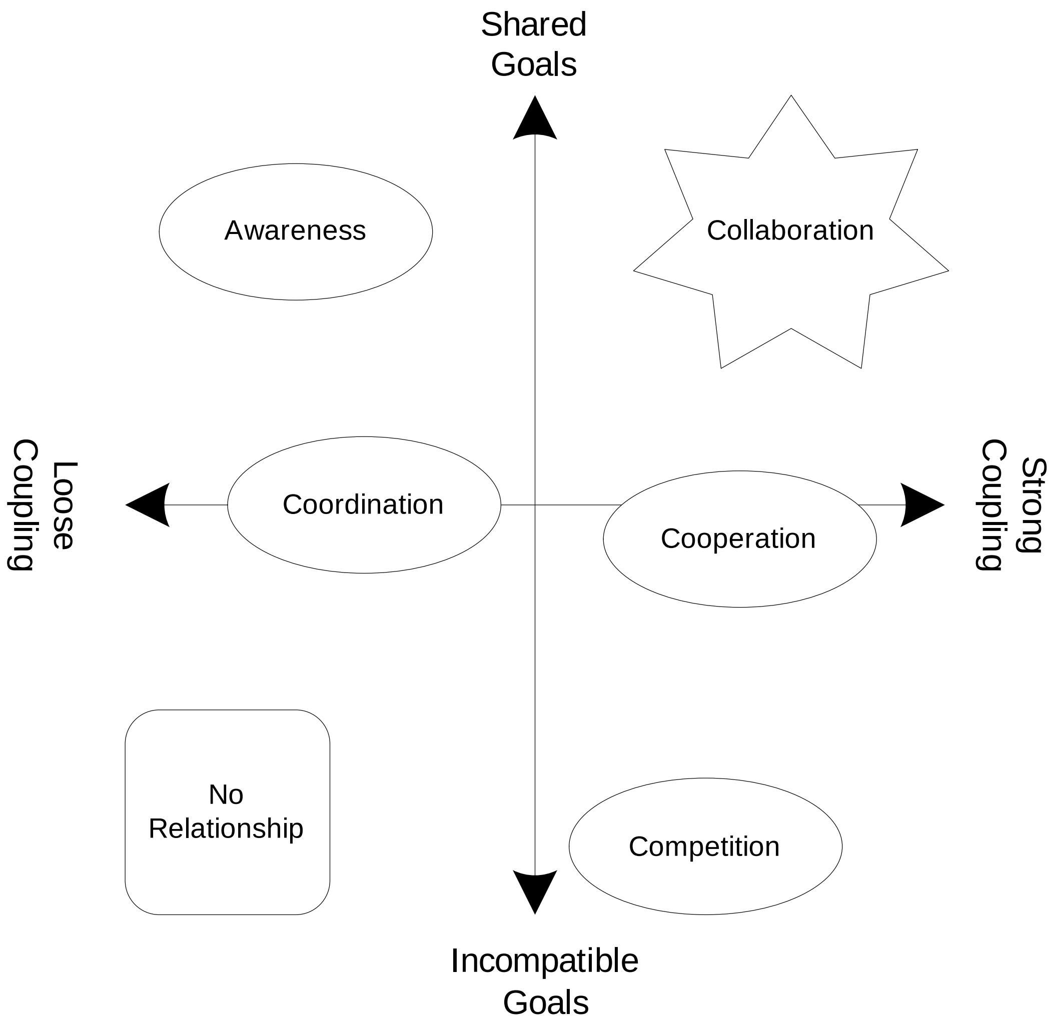

Figure 2.3. The ways in which group members interact.

Collaboration, therefore, is the term used in this thesis for group work where the group members have some shared goal and the things that they need to do to achieve that goal are strongly interdependent. Each of the other categories is in some way a variant of this.

In this thesis, cooperation is defined as group work where group members have tasks that are strongly coupled, but are not bound by a single shared goal and coordination as individual work of the same nature. Competition is defined as work on tasks that are strongly coupled to each other, but those tasks are being completed in pursuit of incompatible goals.

Pinelle et al. (2003) developed a series of primitives, termed the *mechanics of collaboration* (table 2.4), which they used to describe the very low-level functions that take place during a collaborative activity. These mechanics have been cited widely in HCI literature, but are too low level for the analysis reported in this thesis, although many of the activities reported could be further broken into a series of mechanics.

Table 2.4. Mechanics of Collaboration, after Pinelle et al. (2003).

	Category	Mechanic	Typical actions
Communication	Explicit Communication	Spoken messages	Conversational; verbal shadowing
		Written messages	Conversational; persistent
		Gestural messages	Indicating; drawing; demonstrating
		Deictic references	Pointing + conversation
		Manifesting actions	Stylised actions
	Information gathering	Basic awareness	Observing who is in the workplace, what they are doing and where thay are working
		Feedthrough	Changes to objects; characteristic signs or sounds
		Consequential communication	Characteristic movement; body position and location; gaze direction
		Overhearing	Presence of talk; specific content
		Visual evidence	Normal actions
Coordination	Shared access	Obtain resource	Take objects or tools; occupy space
		Reserve resource	Move to closer proximity; notify others of intention
		Protect work	Monitor others actions in the area; notify others of protection
	Transfer	Handoff object	Physically give/take object; verbally offer/accept object
		Deposit	Place object and notify

2.5 Co-located groups vs. distributed groups

This section reviews the differences that have been identified between the ways that co-located groups and distributed groups work. The particular focus is on how different GSS have been developed to support these two different types of interaction. Increasingly in the academic literature, GSS have been assumed to relate only to distributed groups; however, this is not always the case, and such an assumption ignores the history of GSS development.

To categorise GSS across simple functional differences, DeSanctis and Gallupe (1987) introduced a 2x2 grid, split between place (i.e., co-located or distributed) and time (i.e., synchronous or asynchronous). From this simple categorisation, it is reasonable to assert that any GSS will be designed to support people working together in the same place, at the same time, both, or neither.

Grudin (1994b) found the 2x2 grid to be insufficient to express the different needs that GSS are designed to meet and extended it to a 3x3 grid (see figure 2.4), so that the level of predictability of asynchronicity and distribution can be expressed.

		Time		
		Same	Different but predictable	Different and unpredictable
Place	Same	Meeting facilitation	Work shifts	Team rooms
	Different but predictable	Tele-conferencing	e-mail	Collaborative writing
	Different and unpredictable	Interactive multicast seminars	Computer bulletin boards	Workflow

Figure 2.4. Groupware options, with examples of type, after Grudin (1994b).

The categorisation is generally used to identify a primary use for a GSS, although emergent behaviour sometimes means that the system is not used for its intended purpose. For example, sometimes people use e-mail to pass files electronically prior to a meeting. This means that although the intended use of the tool is to provide distributed asynchronous communication, both sender and recipient may ultimately sit down together in front of the same e-mail client at the same time and review the contents.

Another change, since Grudin proposed these categories in 1994, is the explosion of pervasive computing and, in particular, portable/mobile devices. This shift away from desktop computing means that more GSS are accessible at unpredictable times and in unpredictable places than when the model was first presented. Again using e-mail as an example, the sender now has far less of an idea when, where or how their intended recipients will retrieve the sent message.

The disadvantages of distributed groups when compared to co-located groups of the same nature have been well documented in recent times. Becker-Beck et al. (2005) found that asynchronous distributed group work was also generally less effective that synchronous distributed group work. However, supporting technologies that go beyond their primary function can offset these disadvantages. Usually this primary function is to enable communication between the distributed group members; this communication may have many streams and be a mixture of synchronous and asynchronous media.

Early Groupware Communication Support Systems (GCSS) focussed entirely on finding effective ways to manage communication between people while they were in different locations. These systems needed to be flexible, so that they incorporated the range of media that could fully support distributed workers (Lim and Benbasat, 1991).

Further research has enabled these systems to be extended, so that the overhead of the communication technology can be put to work so that the systems also are used as Groupware Decision Support Systems (GDSS). At various levels the communication can be captured and used to support decision making within the group. This extra utility leads us to ask how the lessons learned from the development of distributed systems can be reapplied in co-located settings. This distinction between GCSS and GDSS was made by Pinsonneault and Kraemer (1989), although GDSS have existed in some form for over 25 years now (Ackermann and De Vreede, 2001).

Allen (1990) noted in an early review of the domain that groupware 'can both enhance a group, and productively insulate members from the group'. One reason for this insulation in the co-located setting is that, unlike in distributed groups, members of co-located groups are normally able to communicate directly (sometimes this is not the case, e.g., a jury during a court session, etc., but the research in this thesis is restricted to groups that are able to communicate). Therefore any support system that attempts to capture and use this communication is a pure overhead. Although the capture mechanisms themselves are becoming increasingly cheap and easy to use, structuring the captured information usefully and without intrusion is very difficult. As its only payback to the group is as a GDSS, rather than being a convenient by-product of the GCSS, captured information must support decision making within the group.

Olson et al. (1991) performed an in-depth study of co-located problem-solving work groups, responding to earlier studies that were inconclusive on the benefits of introducing technologies into such groups. They concluded that, in the instances of their study, the design groups they observed did get payback from the support system in question; however, they also discovered that 7% of these groups' time was spent trying to work out how to use the new technology.

An important question to ask is *at what level and for which purposes can a GSS most effectively support a co-located group?* The answer to this question depends on many factors, such as the specific nature of the task and the make-up and size of the group, but the focus of this thesis is how groups can be observed and generalisations made in such a way that useful GSS can be developed for co-located groups.

One way that GDSS are traditionally used to support co-located meetings are through a person or other agent acting as a facilitator. This provides the group with both a decision support tool and a GDSS expert who can act as the interface between the technological support and the other human participants. The perceived need for a specialist to take this role in co-located meetings to make GDSS support effective shows the difficulty that designers have had in engineering a more closely-coupled relationship between the support tools and the group as a whole.

Antunes and Ho (2001) developed and reported an interesting variation on the facilitator-led GDSS by suggesting the use of a meeting preparation tool, whereby the facilitator uses the GDSS to prepare for meetings, which they then chair, as well as using the tool to support decision making within the meeting.

Saïkali and David (2001) identified Workflow Management Systems (WMS) as a distinct category from those of GSS. They state that GSS focus on collaborative work as their main process, whereas WMS are designed to support the management and automation of processes. Furthermore, they found that GSS and WMS differed on fours levels:

1. The *purpose* level. For WMS this is process management and coordination; for GSS this is group support and sharing.
2. The *interaction granularity* level. GSS are located at the activity level, whereas WMS are located at the process level.
3. The *interaction mode* level. This is asynchronous for WMS, but could be either synchronous or asynchronous for GSS.
4. The *mutual awareness* level. Users of WMS need not necessarily be aware of each other's activities, whereas one of the main purposes of GSS is to improve mutual awareness to allow collaboration.

Essentially, a WMS supports coordination in the workplace, whereas as GSS supports collaboration. Referring back to the diagram representing different types of group interaction (figure 2.3), it is apparent that WMS are a class of tool designed to support task-oriented work, whereas GSS are a class of tool designed to support goal-oriented work. Despite identifying these main distinctions, Saïkali and David (ibid) point out that the functional divide between the two types of support system can be bridged to create hybrid systems that support some or all of the facilities of both.

There are many real world situations where work groups need supporting in a mixture of coordinated and collaborative activities, of which some are co-located and others distributed. For example, home care for the elderly (Orre and Middup, 2006), where the implementation of a hybrid system allowed the carers to both schedule their work (the characteristics of a WMS) and to record and share important care information about their clients (the characteristics of a GSS).

Another type of GSS that has evolved in the corpus of Knowledge Management (KM) research is the Group Memory System (GMS), as proposed by Vasconcelos et al. (2000). They define a GMS as ‘a system to manage heterogeneous and distributed knowledge embedded in business process activities’. This type of GSS is aimed at supporting organisations at a high level, i.e., something that adds knowledge to corporate-wide information in large organisations.

Although this level of focus is different to the small group level of this thesis, the link between knowledge and process is an important one that is developed and expanded upon here.

2.6 Conclusion

This chapter has reviewed and situated literature from a number of disciplines to explain how small co-located problem-solving work groups are represented. It looked at this in terms of the people that comprise these groups, the tasks that they perform and the technologies that support them. Using the characteristics of people and technology, the discussion has reflected upon exactly what it means for members of such a group to collaborate.

Of the many different fields of research, the work presented in the remainder of this thesis is most relevant to Computer-Supported Cooperative Work (CSCW), and the case for the contribution of this thesis being situated within the CSCW field is made.

In the next chapter, a first study is introduced and used to illustrate the difficulties in identifying group-level dynamics; this is then used to situate the remainder of the thesis.

3 Understanding Group Constructs

> Ironically, the more independent and autonomous we get, the more we have to learn to work with others.
>
> From *The Hungry Spirit*, Charles Handy (1997, p140)

In the previous chapter, the thesis proposed a definition of 'task' and in particular argued which types of task can be described as 'simple' tasks and which types can be described as 'complex'. This chapter addresses the question, 'how extensible is an understanding of simple tasks in trying to understand complex tasks?' Also, because the aim of this thesis is to present a better understanding of how groups complete complex tasks, the use of group-level metrics and the problems associated with identifying and measuring characteristics at a group level, compared to those at an individual level is investigated and discussed.

To achieve this, an initial study, based on groups of three people attempting to complete a jigsaw, is introduced. The thesis makes use of the analysis of this study to reason about task identification and task complexity (a short description of this study and some early aspects of the analysis were first published at the 39th Hawai'i International Conference on Systems Sciences (Middup and Johnson, 2006)). This leads on to the introduction of individual- and group-level metrics that can be used to measure the overall effectiveness of a group meeting. This study was deliberately small in scale, and was devised to reason about points of interest in collaborative co-located group work that is researched and reported more rigorously in later chapters of this thesis.

There is much discussion in the literature about how best to approach using individual group member attributes to identify their equivalent group-level metric. Often group-level attributes are harder to validate, because although a person can give an individual validation of any assumption made about them, there is no equivalent 'single voice' that can give a definitive answer for a group. Statistical methods to mitigate this problem have been proposed (e.g., Walczuch and Watson, 2001, who suggest that a hierarchical ANOVA method should be used for group level analyses), but the essential problem remains that whilst a group is a notional single entity, it fundamentally remains a collection of people. The jigsaw study focuses on the measurement of *self-efficacy* (Bandura, 1977) and the difficulty of using this as a measure of the group-level equivalent, *collective efficacy*. Self- and collective efficacy were chosen not only because they are established measures that can provide an interesting insight into group effectiveness, but also because there is a long-standing and ongoing academic debate about how to use the individual measures to inform the group-level measure.

A second group attribute considered in the analysis of the jigsaw study is that of *group memory*. In a similar way to Bandura's theories of efficacy, the notion of memory becomes problematic once an attempt is made to understand it at a group level. The ways in which self- and collective efficacy are constructed and modified within the group, as well as the manner in which they change over a few days after the task, are interesting pointers to where GSS intervention might be most appropriate in supporting groups to achieve maximum effectiveness.

3.1 Self- and collective efficacy

Bandura's (1977) theory defines self-efficacy as a person's belief in their ability to perform some function or to achieve some goal through their own actions. Without such a belief, their incentive to act and to be responsible for their actions is diminished. Self-efficacy is directly related to a person's performance in a given situation, but this effect can be moderated by the complexity of the task (Stajkovic and Luthans, 1998) or if there is no clear goal (Cervone et al., 1991). It is also threshold driven, in that passing a certain threshold of self-efficacy will result in a change of behaviour, whereas changes of strength of self-efficacy above and below that threshold might have no noticeable affect (Bandura, 1997). This threshold is often the trigger for agency – ie, a certain level of self-efficacy will allow someone to perform a particular activity, whereas below the threshold they will not make the attempt.

Bandura (1997) identifies four main categories that act as sources of self-efficacy, which are a revised and renamed set from his earlier work (Bandura, 1977); these are *enactive mastery experience*, *vicarious experience*, *verbal persuasion* and *physiological and affective states*.

Enactive mastery experience describes how success enhances a person's self-efficacy, whereas failure undermines it. Experience of success or failure before a person's self-efficacy in a particular category is well established is particularly influential. Later, the feedback of ongoing success or failure into a well-established self-efficacy belief will lead to more moderate changes.

Vicarious experience is drawn from available comparisons to information and people around ourselves and modelling it. Rather than the explicit knowledge of success or failure from enactive mastery, this experience has a normative basis and is reliant upon the normative information available.

Verbal persuasion can increase self-efficacy if it is realistic. It requires a bond of trust to exist and be maintained between persuader and their target, which in turn relies on the persuader providing realistic verbal persuasion and other circumstances ensuring that their persuasion remains a believable reality.

Physiological and affective states provide another form of direct feedback that will result in self-efficacy judgments. As well as in obvious situations, where physical ability is critical, this category is also relevant to stress and other measures providing feedback that is used implicitly in self-efficacy evaluation. Bandura (1997) points out that attention is a limited resource that, when not focussed externally, is more likely to focus internally instead.

Self-efficacy is not the same as self-esteem (Bandura, 1997). Self-efficacy is a judgement of one's personal capabilities, whereas self-esteem is a judgement of one's self-worth. Bandura claims that there is no fixed relationship between a person's self-efficacy and their self-esteem. Importantly, self-esteem and self-efficacy are also measured at different levels; self-esteem is a single opinion of oneself, whereas self-efficacy is a series of task-specific evaluations (Gist and Mitchell, 1992).

However, it seems unlikely that self-esteem and mood are not contributory factors in a person making judgements on their own capabilities. Cervone et al. (1994) observed that experimentally induced lower moods led to another type of spiral effect. In this case, a depressed mood led to low self-efficacy but a higher estimation of the necessary standard of performance for success in a task. Following on from this, the person is less likely to believe they have been successful in an activity, which further lowers their mood and their self-efficacy.

Self-efficacy is continually evaluated through a triadic reciprocal causation between one's behaviour, internal personal factors and the external environment (Bandura, 1997). In this context, 'causation' means that there is a functional dependence between the three events, and so the three all influence and affect each other.

Through behavioural choices self-efficacy can affect performance in either a positive or a negative manner. Lindsley et al. (1995) claim that the relationship between self-efficacy and performance is cyclic. By turn, each variable alternates between being cause and affect and a sequence of these iterations can lead to a spiralling effect. Both positive and negative spirals can have a negative affect on future performance, therefore self-correcting cycles are advocated.

The various means by which a person gathers information that they can apply to self-efficacy judgements should be thought of as a mix, rather than isolated information that might be acted upon. An individual's perception of self-efficacy, or re-evaluation of it, will be as a result of an integrated appraisal of a number of performance determinants (Gist and Mitchell, 1992).

That someone's belief in their capabilities influences their behaviour is an easy theory to accept, but a difficult one to measure. Initially, it seems trivial, because whatever someone says about a belief (if they're telling the truth) is his or her belief. However, the main difficulty is in determining a suitable set of efficacies to quantify and at what granularity. It may well be that two people associate themselves with moderate self-efficacy in a certain category, but if this is split into four sub-categories, the aggregation might be comprised of very different peaks and troughs.

Choosing the correct range and granularity of measures is highly task-specific, which presents a problem in both comparing the effect of self-efficacy on behaviour over a number of tasks and in comparing different studies. In this study four high level categories of self-efficacy are used; these were chosen to be representative of characteristics that could be compared against other research.

Collective efficacy, also known as *group efficacy*, *group potency* and *collective self-esteem* (Marks, 1999), is the extension of self-efficacy to something that exists at a group level (either as a collection of individual efficacious beliefs, or as a set of group-emergent properties). It is the collective belief in a capability or capabilities that enable group behaviour that will achieve particular goals or produce specific actions. The term *collective efficacy*, for the purpose of consistency, will be used hereon.

The extension from self-efficacy to collective efficacy is problematic, because many other group dynamics influence a group's behaviour. This prevents measuring collective efficacy directly from the group's members' self-efficacy being straightforward. Bandura (1997) claims that collective efficacy cannot be derived as a sum of personal efficacies, because of the influence of other group dynamics.

One such dynamic is team leadership. Taggar and Seijts (2003) show that well-formed leader and team member behaviour leads to the highest levels of collective efficacy. This suggests that a hierarchy of efficacious beliefs may be present, where certain thresholds of super-ordinate self-efficacies might render other sub-ordinate ones irrelevant. In this case, high leader or member role-efficacy can only compensate to a certain point for a weakness in the other one and overall will be a limiting factor on the performance of the team, regardless of other task-related group efficacies.

Leadership self-efficacy is also linked to anxiety (Hoyt et al., 2003; Murphy, 2002), where those with a high level of perceived efficacy belief in their leadership are less likely to become anxious in stressful situations. Those leaders that exhibit least anxiety demonstrate the most robust performances in such situations and, therefore, contribute more strongly to high collective efficacy. Murphy (2002) also notes that self-monitoring is important, giving leaders behavioural flexibility that can improve performance, an observation that fits well with Bandura's (1997) concept of enactive mastery experience.

Pescosolido (2001) showed that informal leaders within a group have a key role in shaping collective efficacy, particularly early on in a group's life. This influence fades over time, as the group gains more situational and contextual data to base their efficacy decisions upon. However, in groups that select and define their own goals, the influence lasts longer because the group's effort is directed early on through the influence of the informal leader and their knock-on effect on collective efficacy. This initial impact, followed by its gradual reduction, may be a reason why Murphy (2002) noted that people tend to overestimate a leader's influence on performance.

Another trait that affects the extension of self-efficacy to collective efficacy is that of attribution. Self-efficacy may be protected in a failing group by blaming external factors such as collective efficacy, whereas in a high performing group individual self-efficacy might be enhanced without giving appropriate credit to the group (Lindsley et al., 1995).

This type of behaviour supports the concept of attribution theory, where either internal or external attribution is selected by an individual to provide the best account of themselves in a given scenario.

Bandura believes that collective efficacy is an emergent group-level attribute and needs to be explicitly drawn from the group, by asking them collectively to define their perceived collective efficacy. Other researchers disagree (Pescosolido, 2003; Zellars et al., 2001) and take the measurement either as an aggregate of self-efficacy beliefs or as an aggregate of each group member's personal collective efficacy beliefs. Lindsley et al. (1995) suggest that aggregating self-efficacy beliefs as a measure of collective efficacy is theoretically weak because is fails to account for group level processes, or acknowledge the group as an entity. They consider the other methods to be appropriate in different circumstances: aggregation of each individual's opinion of collective efficacy can be helpful in groups where it would not be easy for any individual to hold a holistic view, whereas Bandura's method is the most appropriate where the group is small and tightly focussed. A comparative study by Whiteoak et al. (2004), however, claimed that there was no great difference between the main measurement methods in assessing collective efficacy.

Despite inconsistencies and divisions over measurement, research into collective efficacy has consistently shown that the greater a group's confidence in its collective capabilities, the more it is able to achieve (Marks, 1999; Bandura, 2000; Pescosolido, 2003).

There is some evidence that normative information supplied with group goals affects collective efficacy and either limits or drives performance (Whitney, 1994). Groups with productivity tasks perform better if they are told that a higher attainment is normal in advance, so long as the target is within the boundaries of what they collectively believe to be possible.

Such a result shows signs that a group might apply the anchoring and adjustment heuristic (Tversky and Kahneman, 1974) when it internally assesses its collective efficacy in light of a specific task. Presented with a low normative value, the group will anchor to it and not independently assess its capabilities based on its pre-existing perceived efficacy. Alternatively, presented with a high normative value, a similar lack of adjustment downwards is evident.

There is little evidence of explicit research into links between collective efficacy and heuristics, despite the strong link between self-efficacy and heuristics at the individual level. The reason for this is that the heuristics themselves have not been extended to form an equivalent set of group heuristics. However, it seems likely that when a group is considered as a single entity, it will find itself in similar situations to individuals, where the complexity of a situation requires or implicitly forces a rule-of-thumb approach.

The concept of *group polarisation* (Pescosolido, 2001) might also be considered an emergent group-level judgment heuristic. When the group tends towards a more risky or conservative approach to a problem than its composite individuals, then it is applying an automatic rule-of-thumb at the group level. Pescosolido shows that the group's leader strongly influences the direction of polarisation.

3.2 A Jigsaw Study

Two groups of three student volunteers were set two tasks, i.e., they were set one task, which they completed, after which they were set a second task. The group size was selected to represent the minimum number of participants that is generally accepted as a group (Fjermestad and Hiltz, 1999), without being too many participants for everyone to make a reasonable contribution towards taskwork collaboration. The two groups did not work together or cooperate; they both attempted the same tasks, but on different days. None of the participants in either group had previously worked together.

Prior to undertaking the study, there were a number of assumptions that could be made by drawing upon findings presented in the existing literature; the thesis does not claim them to be hypotheses, as the purpose of this study was exploratory and not intended to conform to experimental rigour. The assumptions made were:

- Performing a group task will affect some key measures of self-efficacy in its members
- Meaningful comparative measures of group efficacy can be drawn from these changes
- Over time, the outcome of the task will have a reduced effect on self-efficacy
- Memory losses will enhance attribution errors

The first task, which was trivial, was designed to act both as an icebreaker and to give an early indicator of potential leaders within the group. The group members were asked to each say a place that they liked, another place that they disliked, and why. The groups were told that they could answer in any order, and the place could be a country, city, building, room or and distinct location of any size.

The second task, which was the main purpose of the collaboration, was to select and complete a 120-piece jigsaw. There were three jigsaws to choose from, each showing a picture of dinosaurs in a mixed habitation environment. The time limit was chosen specifically to be just short of the time really required to complete the exercise, based on an estimate from a previous study of the time taken for pairs of people to collaborate on completing the same jigsaws (Johnson and Hyde, 2003); the purpose of this was to force an element of time pressure into the groups' interactions. A jigsaw was chosen as the task for a number of reasons: it is a problem-solving task that most people could reasonably be expected to be able to attempt, regardless of direct prior experience; it is compact for recording purposes and it is achievable within a reasonably short time period.

The setting for the group exercises was the HCI laboratory on the University of Bath campus. There was a main table for the participants to sit or stand around, as well as a desk each for them to complete pre- and post-study questionnaires in privacy. The sessions were recorded with two fixed cameras, one with a narrow focus on the central table and the other with a wide focus of the whole room; audio was also captured. The purpose of these recordings was for analysis only and they were not made available to the participants. This study, using the Poole et al. (2004) classification (described in Chapter 2), is both a temporal and psychodynamic study that investigates how the group work affects individual and collective dynamics during the meeting and beyond.

Prior to the first task, the participants were asked to complete individual questionnaires, comprising 20 questions (see figure 3.1) with tick-box answers on a five-point Likert-scale with the option of choosing: *strongly disagree*, *disagree*, *neither agree nor disagree*, *agree* or *strongly agree*.

Leadership

1. If the group is stuck, I will take charge to solve the problem.
2. If someone else talks a lot, I usually let them, even if I don't agree with what they are saying.
3. I like to work my own way, even if it differs with other group members.
4. I enjoy confrontation.
5. I am comfortable leading a group if it is performing a task that I am familiar with.

Trust

1. I believe that I generally try harder in groups than other people.
2. I generally trust other people in groups to work towards our shared goals.
3. I do not trust people implicitly; I like to reserve judgment until I know them.
4. I believe that other people work harder if there is a reward for them to do so.
5. Team members that work together often, develop mutual loyalty.

Problem Solving

1. I find it easy to organize tasks into a series of appropriate activities that allow me to complete the task.
2. I take a logical approach to problems.
3. I am confident of my ability to solve problems because of prior experience.
4. I easily see links between different types of task and use them to help me complete the job in hand.
5. I believe that I can solve problems through simple logical steps.

Communication

1. If I have something to say, I will always say it, even if I'm not sure that I'm right.
2. If I think that people aren't listening to me, then I will stop trying to help them.
3. I always listen to what other people are telling me.
4. I find it easy to communicate with people, even if they are from different backgrounds to me.
5. It is easier to talk to people if I can see them.

Figure 3.1. Likert-scale statements used prior to the exercise

There were five questions designed to capture each of four high-level self-efficacy beliefs: leadership, trust, problem solving and communication; the interpretation of what these beliefs mean to an individual are expressed in table 3.1. The questions were randomised in the questionnaire, so that the categories were not apparent to the participants.

Table 3.1. Self-efficacy categories used in the exercise

Belief	Definition of Self-efficacy
leadership	Self-efficacy in leadership is an individual's belief in their ability to lead other people. Here it is important to make the distinction between *ability* and *capability*. A person may believe that external factors are adversely affecting their capability to lead, whilst still believing that they have the ability to do so.
trust	Self-efficacy in trust is an individual's belief in their ability to trust other people in a group that they are a member of.
problem solving	Self-efficacy in problem solving is an individual's belief in their ability to solve problems. Again, this relates to belief in ability rather than capability, so relates to the strength of belief in answering questions such as "Are you good at solving problems?", rather than "Do you think you could solve [a problem]?" One difference between the individual's self-efficacy in this category and the other three described here is that it can be drawn from individual activities as well as shared ones, whereas the other three are all drawn from human-human interaction.
communication	Self-efficacy in communication is an individual's belief in their ability to communicate effectively with other people in a group.

Following the completion of the second task, or at the end of the available time, the participants were asked to complete a second individual questionnaire. For this, there was an equivalent set of Likert-scale questions (see figure 3.2), again jumbled, this time making specific reference to the jigsaw task. The purpose of this was to identify potential changes in self-efficacy from participation in the group exercise and to test the hypothesis that changes to self- and collective efficacy, following a group activity, are initially closely tied to the outcome of that activity.

Leadership

1. When we couldn't find the right piece, I suggested alternatives to keep us progressing.
2. I let other people control the group, even when I thought I had a better approach to completing the jigsaw..
3. I took my own approach to completing the jigsaw, even if others were doing different things.
4. There was competition within the group.
5. Familiarity with jigsaws meant that I took control and led the group.

Trust

1. I was more committed to completing the jigsaw than my teammates.
2. My teammates seemed to have personal objectives beyond the task itself.
3. Based on my experience today, I would select these people to be my teammates for other tasks.
4. I thought that the task was too trivial for my teammates to be fully committed to completing the jigsaw.
5. I believe that we gelled as a team.

Problem Solving

1. I was able to easily break down the jigsaw problem into a series of smaller tasks.
2. I applied a logical approach to completing the jigsaw.
3. I used prior experience of jigsaw puzzles to help the group complete the task.
4. I used prior experience of different types of problems to help the group complete the task.
5. It was easy to complete the jigsaw because I could see a logical order for completing it.

Communication

1. Throughout the exercise, I tried to keep things going by making suggestions to my teammates.
2. I found that my opinions weren't really required for us to complete the jigsaw.
3. As we attempted the puzzle, I always listened to my teammates opinions.
4. I found it easier to communicate with one teammate than the other.
5. If the puzzle had been on a screen and my teammates in other rooms, I think that this would have been a more difficult task.

Figure 3.2. Likert-scale statements used after the exercise

The selection and definition of the categories and the questions in the questionnaire were all defined by the author of this thesis as part of the development of the study. The effectiveness of these ideas and methods are reflected upon later in this chapter, along with other outcomes from the study.

Ten days after the group exercises, each participant was invited to return for an individual interview, structured to investigate their memories of the group exercise and also to test the longer-term effect on self-efficacy. The data from these interviews is used to consider the second hypothesis, that memory deficiencies and inaccurate attribution mitigate the effect that direct experience has on an individual's modification of self- and collective efficacy. The interviews lasted between five and 10 minutes, depending on the length of answers, and audio recordings were made.

3.3 Results from the study

In this section, the participants from group one will be referred to using the anonymous tags M1, M2 and F1 and the participants from group two will be referred to as M3, M4 and F2 respectively. In the design of the study, and later in the analysis, there is no distinction made according to the gender of the collaborators; however, male participants have an Mx tag, whereas female participants have an Fx tag; each group, coincidentally, comprised two male participants and one female participant.

The first objective was to use the pre-exercise questionnaires to give a baseline for each of the participants' self-efficacy beliefs of leadership, trust, problem solving and communication. Each answer was given a numerical value: strongly disagree, -2; disagree, -1; neither agree nor disagree, 0; agree, 1; strongly agree 2. For some questions these values needed to be reversed to reflect the negative nature of the question itself and allow the overall value within each category to be calculated. This was achieved by summing these values within each of the four categories to produce the values displayed in Table 3.2. The purpose of measuring self-efficacy in this way was to produce values that would be directly comparable to similarly acquired values once the study was completed, and the longer-term effect after several days, could be measured.

Table 3.2. Aggregated results of pre-study questionnaire

		Leadership	Trust	Problem Solving	Communication
Group 1	M1	+4	+3	+2	+4
	M2	+2	+2	+4	+1
	F1	+3	+4	+5	+4
Group 2	M3	-1	+4	+5	+2
	M4	+3	+1	+1	+1
	F2	-2	+2	+3	+4

The pre-exercise questionnaires showed that, in terms of self-efficacy, there would be more competition for leadership of the first group; in the second group, responses suggested that

M4 would be the emergent leader. An early indication of this was in the icebreaker exercise, where M4 took the initiative to speak first.

All participants indicated, prior to the group activity, that they believed they had an implicit trust of other people, until first-hand evidence was available. For example, every member of group one disagreed with the statement “I do not trust people implicitly; I like to reserve judgment until I know them”.

Similarly, all participants showed some degree of self-efficacy in problem solving when answering abstract questions about their own beliefs in their ability. M4, the participant with the lowest self-efficacy in problem solving, as captured by the questionnaire, was generally the most ambivalent in his answers, so the questions may have been too general for him to feel a strong response was necessary.

The final category, communication, suggested that M2 might be left out in the first group and that F2 might dominate communication in the second.

In a co-located group, verbal communication has a direct impact on each of the categories of leadership, trust, problem solving and communication. Observations from the recordings of the group exercises were used to capture the verbal communication, so that it could be used for two purposes. The first purpose was to use the data to analyze how the groups performed, and to relate this to their opinions of self- and collective efficacy. The second purpose was to compare the external observations against the recollections of the participants on how their group communicated, captured by questions in their individual follow-up interviews. This data could then be used to investigate both memory deficiencies and attribution, to see if they had an impact on long-term self- and collective efficacy.

During the jigsaw exercise, verbal collaboration between participants took several forms, occurrences of which have been categorized as *questions*, *directions* and *suggestions*. The purpose of these simple categories were to get a feel for the confidence of participants within the group – this idea is developed in Chapter 5, where SYMLOG (Bales and Cohen, 1979) is used to establish a more comprehensive analysis of group members’ mood towards their task and towards their team. Here, it became clear that there was potential for overlap between categories, as many intentions can be phrased as a question, even when no answer is required, so observers additionally needed to judge the intention of the utterance from cues such as tone of voice or inflection. Table 3.3 provides definitions for the three categories that minimize the problem of misinterpretation.

Table 3.3. Utterance categorisation for study analysis

Utterance Category	Definition
question	The type of utterance categorised as a question in this study is restricted to questions asked that clearly and honestly require an answer to something that the questioner does not know. This is still a judgment call for the observer, but removes the inclusion of rhetorical questions, unusual voice inflections, etc.
direction	This type of utterance could equally well be termed "instruction", as it categorises the instances when one group member gives another or others a directive or instruction.
suggestion	This type of utterance is when the speaker offers a solution but in the way they phrase the utterance they give other group members the opportunity to query or modify what they propose.

The first group {M1,M2,F1} spoke to each other much more than the second group, so the incidence rate of questions, directions and suggestions is much higher.

Within the first group, there was an emerging leadership battle between M1 and F1, which may partially explain the increased amount of dialogue. Although M1 asked a lot of questions, many of these were phrased openly to keep the group going, e.g., "OK, what's next?". F1, by comparison, made more focused suggestions, giving the impression that she already had a vision for the task and required the others to comply with this.

The totals of each type of utterance are shown in table 3.4, grouped by each participant.

Table 3.4. Utterances counts of each jigsaw study participant

		Questions	Directions	Suggestions
Group 1	M1	23	5	5
	M2	4	8	7
	F1	14	2	12
Group 2	M3	1	1	2
	M4	4	1	2
	F2	0	1	1

As the groups have no previous history and the time spent together performing this task was very short, there is insufficient time for the group to progress very far through Tuckman's forming, storming, norming, performing group development cycle (Tuckman, 1965). The dialogue approaches of M1 and F1 indicated the beginnings of the storming phase, as each sought to direct the group in a different style.

The second group stuck to their plan throughout and with very little dialogue, failed to move beyond the forming phase.

Although the first group appeared to get on less well with each other than the second group, they were actually more effective, in that they got much closer to completing the jigsaw within the time allowed; in fact, they only had 20 pieces left to place when the group was stopped after the allocated 15 minutes, whereas group two still had over half the pieces (65) unplaced. One explanation for this is that the teamwork activities involved in storming added some competitive zeal that allowed the first group to become more focused on the main jigsaw task; it also suggests that, in this instance, the efficiency gain from the dialogue more than overcame its production-blocking overhead.

After the second exercise, the purpose of the post-exercise questionnaire was to capture how the participants felt their beliefs in leadership, trust, problem solving and communication had changed as a result of completing the group exercise. The questionnaire was designed to capture data that could be used to investigate how self- and collective efficacy are initially impacted by a group exercise but, later, other factors reduce this effect.

The post-exercise questionnaire is summarized in Table 3.5, using the same aggregation method described for the pre-exercise questionnaire, but the questions were focused specifically on the recently undertaken jigsaw task.

The results of the second questionnaire support the observations that have been described. In the first group, where no clear leader and no clear approach to the task emerged, belief in leadership, trust and communication all dropped dramatically, although two group members still demonstrated a strong belief that the problem-solving aspect of the exercise had gone well.

Table 3.5. Aggregated results of post-study questionnaire

		Leadership	Trust	Problem Solving	Communication
Group 1	M1	-1	+2	-1	-1
	M2	-1	+1	+3	-5
	F1	0	0	+4	0
Group 2	M3	-3	+5	0	+2
	M4	+3	+2	+6	+1
	F2	-1	+4	+5	+2

In the second group, the self-assessment of leadership matched the observations of the exercise and the self-efficacy profile. Despite these differences in leadership rating, both M3 and F2 disagreed with the statement "I let other people control the group, even when I thought I had a better approach to completing the jigsaw.", whereas the emergent leader, M4, neither agreed nor disagreed with this statement. This profile fits with the higher trust measurements recorded for M3 and F2 in the post-exercise questionnaire.

Trust and communication measures also remained similar to the prior self-efficacy measures; this fits with the second group's approach of organizing into individual sub-tasks, before collating towards the end of the exercise. Similarly to the first group, the post-exercise questionnaire revealed that two of the participants were very satisfied with their problem-solving performance in the exercise, with the third participant not satisfied at all.

Interestingly, only M4 agreed with the statement "I used prior experience of different types of problems to help the group complete the task." Given the range of basic skills required to perform a simple collaborative task, it was surprising that the other participants were unable to relate this to any prior experience.

In the follow-up interviews, which took place ten days after the initial exercise, a range of questions were asked to capture each individual's memory of the exercise and any potential changes to self-efficacy. The purpose of this was to gain some insight into the prior expectation that memory deficiencies and inappropriate attribution lead to self- and collective efficacy not changing as much as the actual events might be expected to cause.

First, recollection of the icebreaker exercise was tested. Of the six participants, only M1 was unable to remember the places they had named as liking and disliking. The others were each able to recall both places they previously named and the original reasons that they had given.

Next, who chose the jigsaw was asked, and why. Members of the second group were all very clear that M4 had suggested their jigsaw, as it had more distinct regions of colour than the others. With group one, recollection of who chose the jigsaw was less clear: F1 thought is was "everyone"; M1 thought it was M2 and M2 thought it was either himself or F1. These variations in recollection occurred despite the fact group one chose the same jigsaw as group two for exactly the same reason; a fact that they also all recalled accurately.

Each participant was also asked to "describe the approach the group took to the task", followed by "did this emerge as you progressed, or did someone suggest this at the start?" Again, for group two, the recollections of events was very similar: each participant recalled the approach as an emergent one, where each person worked on an individual area before tying together when they were well into the puzzle. By contrast, group one's members seemed to recall both different approaches and different methods for arriving at their approach: F1 thought that the whole approach had been suggested at the start; M1 thought that they had adopted the "natural approach" and M2 thought that it was suggested that they do the edges first and then no more suggestions had been made.

With questions, suggestions and directions voiced by each participant having been counted from the video recordings of the exercise (see Table 3.4), they were now asked "who do you think asked/gave/made the most questions/directions/suggestions during the group exercise?" The purpose of this question was to see if participants could recall the verbal contributions of themselves and their teammates. Given that group two spoke so very little during the exercise and that few of these incidents were observed, it is not surprising that none of this group's members were really sure who led in each of these categories; when they did venture a name, it was always M4, the group's emergent leader.

As neither of the groups completed the jigsaw in time, even though it was made clear to the groups before they began the task that completing it was the objective, it was assumed that the members of both groups would consider their communication strategies to have been sub-optimal; individually, they were asked whether the level of communication was too much, too little or about right. However, in group two, where performance was less good than in group one, everyone thought that their level of communication was about right. Group one, on the other hand, where there was competition for leadership and evidence of storming, reported that more spoken communication would have aided them. Of course, neither group had the opportunity to observe other groups following other communication strategies, so their ultimate view of group performance might be an incidence of groupthink (Janis, 1982).

According to the follow-up interviews, emergent leadership didn't take place as expected. In both groups, the person that most strongly thought they would lead the group, M2 and M3 respectively, did not do so. In group one, F1 did not think that she had led the group, despite the number of suggestions that she made; neither did M1, despite the number of questions that he asked. In M2's opinion, it was M1 that led the group and he was also most satisfied with M1's contribution. It was interesting to note that there was a clear leadership battle in group one, with neither participant believing that they either aspired to leadership or actually took it.

The effect on the various participants' self-efficacy beliefs, by taking part in the group exercise, was captured directly from the following question: "Did performing the group exercise alter how you see yourself in the following roles? (1) An effective leader; (2) a trusting co-worker; (3) an effective problem solver; and (4) a good communicator."

M1 thought that trust had been built up within his group, although he saw this more from the perspective of a collective efficacy of the group. His self-efficacy for trust might also have been raised as an appreciation of this. He didn't think his self-efficacy in the other roles had been challenged by the exercise – commenting that as an effective communicator "it was just a jigsaw", so effective communication was not necessary.

M2 seemed to notice more impact on his self-efficacy. He noted that he had realized that he was not the appropriate leader for any group, and that he felt less effective as a problem solver, because a structure did not emerge to solve the problem in the given time.

M3 found that he was more trusting than he had expected to be and had not questioned the approach as much as he thought he would do prior to the exercise. He also thought that his belief in his problem-solving ability had gone down, because the group had failed to complete the exercise in time. Similarly, his idea of himself as an effective communicator had gone down because he had not spoken as much as he had expected to; he noted that familiarity within a group seemed to be more important than he had anticipated.

F1, F2 and M4 did not think that the exercise had altered their opinions of self in any of these roles, although M4 noted that the communication was not good, he simply did not associate that failing with himself.

3.4 Discussion of findings

The aim of this initial pilot study was to better understand how co-located problem-solving groups collaborate over a shared task. From the observations of this study, some interesting research questions can be proposed that help analyse collaboration and provide insights into how to support group collaboration with technology.

A second aim of the study was to better understand the problem of identifying and measuring group constructs. To do this two individual characteristics, self-efficacy and memory, were used, which have commonly been aggregated to group-level constructs, collective efficacy and group memory. In both cases, there has been no uniformly accepted method of measuring the group-level construct and therefore they seem to be an appropriate starting point for researching the complexities of co-located group collaboration.

Capturing self-efficacy is relatively straightforward because a person's belief in their ability is whatever they say it is (assuming that they tell the truth). It is more difficult to moderate these results over several people, because their relative strength of belief might be expressed in different ways. Additionally, their collective ability may be greater or lesser than the sum of the parts, depending upon how harmonious their individual abilities are. Because of this, a person's self- and collective efficacies might be very different for the same ability.

The questionnaires prior to and following the jigsaw exercise showed that, while close comparison of the quantitative interpretation of self-efficacy is difficult, the trends were generally supported by the behaviour and interaction of the participants. For example, the quantitative measure of leadership self-efficacy from the pre-exercise questionnaire clearly predicts contest for leadership in group one, but none in group two.

At the beginning of the exercise, the existence of collective efficacy was reliant upon the measurement method. If, as Bandura suggests, it is a group-emergent attribute, then collective efficacy cannot be measured for a new group. Alternatively, if it is an aggregation of the equivalent self-efficacy of the group's members, then it can be measured. The measures taken here show the difficulty with the second method. In particular, leadership: aggregating the self-efficacy of the individuals, then group one would register at +9 and group two would be zero. This clearly doesn't represent either the leadership within either group, or the participants' beliefs in the relative leadership of their groups.

Different measures of self-efficacy require different approaches to analysis that might point to the initial collective efficacy measures for a new group. In leadership, a single strong leader might generate a stronger initial belief in leadership. By contrast, if only one participant had registered a strong self-efficacy for trust, then the group as a whole would probably not identify with a high trust level.

The thesis also adds weight to the argument that collective efficacy is a group emergent property, rather than an aggregation of the self-efficacious beliefs of a group of individuals. It may be that the reason Whiteoak et al. (2004) could find no great differences between measurement methods is because there is no effective measure for collective efficacy. It can be shown to exist in certain situations because agency within a group can be taken as proof of a threshold of collective efficacy, but it remains a step further to measure collective efficacy away from the agency threshold.

It was clear from observation of the group activity that the behaviour and abilities of some participants did not match their self-efficacy as captured in the pre-exercise questionnaire. Their self-assessment of their actual performance in the post-exercise questionnaire more accurately resembled that which took place in the activity, but the actual impact of this on their self-efficacy was highly variable.

In the post-exercise questionnaire, the participants were also asked whether their behaviour had been affected by the environment, or the obvious presence of the audio-visual recording equipment. Five of the participants thought that it had no effect, which suggests that this type of technology might be a reasonable "person-technology fit" for most people in a group environment. One participant, M2, commented:

> *I forgot about the recording (although not the time limit!)*

The time limit affected some participants more than others. Some took the 15 minutes set for the task to be the success measure and considered not completing the jigsaw within that time to be a failure. However, neither group was explicitly told that they should complete the task within that timeframe, nor was a clock made available in the room (although participants had their own wrist watches). In the follow-up interviews only M3 thought that his problem-solving self-efficacy had gone down as a result of not completing the task on time. Others either did not consider the task valid, or attributed the failure to other factors.

This attribution to other factors and, generally, where actual performance was not recalled by the participants in a way that they believed altered their self-efficacy can be viewed as instances of "instrumentalization" (Schudson, 1997), where the memories are recalled and shaped to attribute successes to the self and failures to others.

The other way in which the participants' recollections are split from modification of their self-efficacious beliefs may be "conventionalization", in that they believe themselves to be conforming to social norms, or a performance (Goffman, 1969) within the group exercise, so their belief in their own abilities is not being directly tested by either their individual or the group's performance.

After the groups had performed the jigsaw exercise, they should have begun to develop collective efficacies that could be directly attributed to their performance and interaction in the exercise. As this was the first and only time that they had worked together as a group, this could be the only direct experience on which they could draw these conclusions.

To an extent, the post-questionnaire data captures these collective efficacy measures for leadership, trust, problem solving and communication. However, on reflection, more questions about the group as a whole would have enriched this data. The follow-up interview identified that in a storming group, participants' views of the performance of their teammates, and the group as a whole, are far more diverse than for a group that remains tentatively in the forming phase.

3.5

Task Complexity and Generalisability

In the introduction to this chapter, the question of '*how extensible is an understanding of simple tasks in trying to understand complex tasks?'* was asked.

The jigsaw study gave some interesting insights into the problem of solving tasks; upon reflection it showed surprising complexity in the interactions and behaviours of the participants. However, on a continuum of complexity for all possible group tasks it would still be categorised as relatively simple, and, therefore consideration needs to be given to the ways in which it differs from other more complex tasks.

A complex task may require more time than a simple task, because it can be less well understood at the beginning. Also, the jigsaw study was only a single session (for the main task), so it cannot show the effect of time gaps between sessions of co-located work. The findings on individuals' memory about the task when they were asked to recall it 10 days later suggests that there may be issues in bridging these gaps effectively.

Every task may have an optimal number of collaborators – too few, and concurrent activities need to be performed in sequence; too many, and the overhead of the extra teamwork activities required to coordinate the group is greater than the gain from the number of possible concurrent taskwork activities. As the task gets more complex, this optimum may rely more and more upon the individual skills of the group members and how well they cover the requirements of the task; for a task that most people could reasonably-well complete as individuals, such as the jigsaw puzzle, this is likely to have a much lesser effect.

The jigsaw study also showed that collaboration in that task comprised many small events that acted as building blocks towards task completion. It is likely that even in undertaking the most complex of tasks, group members will rely on the same building blocks to construct a collaborative activity. A useful generalisability between both different tasks and different instances of tasks will lie at the level of some set of collaborative building blocks.

3.6 Conclusions

This chapter has presented an empirical study that was used to discover how self- and collective efficacy are affected by group exercises and the group's participants' memories of those events over time. From this, it has discussed how group effectiveness could be improved by helping group members to match their efficacious beliefs more accurately to their abilities.

The study had a small number of participants, who were selected randomly. However, by analysing the data from this study, the following questions are raised:

- Are memories of group events less accurate in a group in the storming phase, rather than one still forming?

- Efficacious beliefs can be very different to actual abilities, although participants in the study could see this difference after the group activity. What are the long-term effects on those efficacious beliefs?
- Some participants associated performance more closely to the task, whereas others associated it more closely with their own abilities. What effect does this have on their efficacious beliefs?
- How easily are verbal communication contributions from a group exercise recalled over time?
- Does uncontested leadership within a group make it easier for the group's members to recall what happened in a group activity?

These tentative first findings showed that further research was needed to understand how collaboration between co-located group members could be better supported. The questions raised about group memory leads to more fundamental questions about how individuals and groups develop the knowledge that they use in shared activities. From the observations of this study, it became apparent that how knowledge is transferred between individuals and groups, and when that knowledge is shared and when it is not are ideas that are critical to both the development and support of effective groups.

The next chapter (Chapter 4) provides a discussion of how this interface between group and individual knowledge is managed and its relevance to any potential support by GSS. This is followed by a larger study of groups (reported in Chapter 5), which analyses the effects of groups working over a longer period of time, with repeated co-located meetings.

4 Knowledge Artefacts and Complex Problems

Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?

from *The Rock*, T S Eliot (1934)

This chapter explores how information is introduced to, negotiated into and adopted by groups. In particular, the concept of both individual and group knowledge represented as artefacts (Stahl, 2006) is used to develop an understanding of how group-level knowledge is constructed and how this supports collaborative group work.

The similarities and the differences between knowledge artefacts and tangible artefacts are discussed, and how these change when viewed from either an individual- or a group-level perspective. From this, an explanation is developed for how the negotiation process that groups undertake in adopting shared knowledge supports the idea of low-level critical events in collaborative group work.

In the second part of this chapter, complex problems and in particular 'the problem of solving complex problems' is discussed in depth. Previously, the thesis described how the analysis of simple problems might inform solving and supporting the solving of more complex ones. In particular, the work of Rittel and Webber (1973) who described 'wicked problems' in the field of urban planning, is drawn upon; this work is critiqued for its relevance to complex and unstructured problems in general and to show how this understanding can help towards a better understanding of collaboration.

4.1 What is Knowledge?

As with many of the other terms discussed in this thesis, the word *knowledge* has a variety of meanings and uses both generally and within academic literature. This section reviews some of the key academic literature and defines the working definition for *knowledge* in this thesis.

According to Ackoff (1989), whose inspiration was drawn from *The Rock* by TS Eliot (Rowley, 2007), the contents of the human mind can be split into the following five categories:

i. *Data.* Data are raw symbols that convey no inherent meaning in themselves. The real importance of data is that it is the collection of basic building blocks for the other categories. Whether the human mind can internalise pure data is a moot point, as to express it in any way at all they must attach context at some level.

ii. *Information.* Information is a collection of data that has been structured in some way to convey a meaning. It answers the 'who', 'what', 'where', and 'when' questions.

iii. *Knowledge.* Knowledge represents the application of information. It answers the 'how' questions.

iv. *Understanding.* Understanding is an appreciation of knowledge, so it answers the 'why' questions.

v. *Wisdom.* Wisdom is an evaluation of understanding, so it is the one non-deterministic level in the hierarchy.

The categories represent a hierarchy, where each level is a proper subset of all the levels prior to it. This means that all information is represented in the data but some data will not represent information; similarly, all knowledge is represented in the information and in the data, but all data and information will not represent knowledge, etc.

Zeleny (1987) proposed a similar hierarchical model, comprising *Data*, *Information*, *Knowledge*, *Wisdom* and *Enlightenment*. The first four categories are similar to those of Ackoff (whose work is more widely cited in the field of knowledge management, rather than Zeleny's, whose work appeared two years earlier). The fifth level, *enlightenment*, really represents reaching sufficient understanding of one's *wisdom*, so that it can be presented to others in a socially acceptable manner.

Ackoff's and Zeleny's four shared categorisations are generally abbreviated to DIKW (representing Data, Information, Knowledge and Wisdom) when knowledge management is being discussed with respect to their work, and are represented as a pyramid (figure 4.1) to illustrate both the order of transition between states and the gradual reduction in the number of entities. Bellinger et al. (2004) explain why *understanding* has been dropped from the hierarchy, stating that understanding is now generally perceived to be the transition between the other states, rather than a state of its own. So, a greater understanding leads to a greater connectedness, which in turn leads to a higher state.

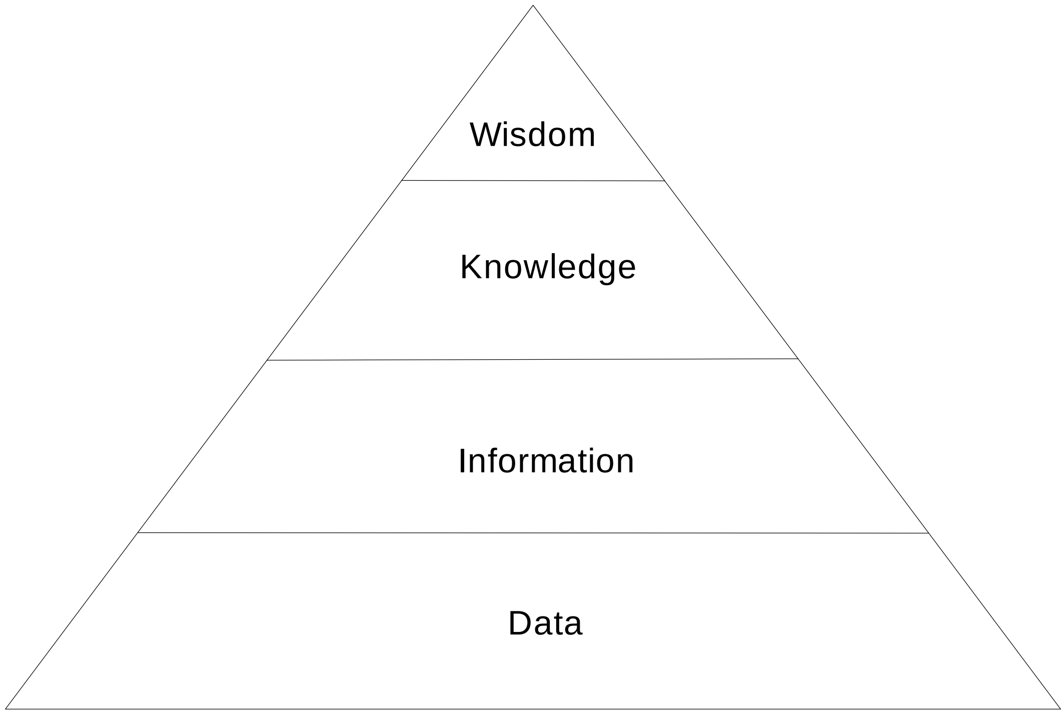

Figure 4.1. DIKW Pyramid, from Rowley (2007)

Despite its wide use and central point in much academic literature, the validity of the DIKW hierarchy has come under strong recent criticism from Frické (in press) as 'unsound and methodologically undesirable'. However, when his criticism of the model is investigated in detail, it appears that his real problem is with its misuse and somehow this leads to the conclusion that the model should be abandoned.

Frické's first criticism of the model is that he believes that information can be inferred from outside current observable data. This is true, but the model merely says that information is drawn from a subset of all our data, so our ability to make inferences is merely an expression of our existing data and information. His second criticism of the model is that data and information in the model have to be true. This would be a fair criticism of the model if it were ever intended, but as a model of the mind it can only ever have been an expression of belief. Knowledge based upon bad information, or information based upon bad data will be incorrect, but that does not make it inconsistent with the model, where each layer is a partial use of the one beneath it. His third criticism of the model is that it does not answer 'why?' questions. As the thesis has described in the history of the development of the hierarchy, an *understanding* layer originally existed that was intended to support this level of awareness, but it was revised to be a means of transition between the other states. Finally, he criticises the model for encouraging uninspiring methodology; he does this by citing examples of poor conclusions from data mining research. His point here is that bad inferences can be made from data, particularly when the inferences use statistical modelling.

Overall, the criticisms seem to stem from an idea that people are like machines and will be able to retain large amounts of data, which can lead to bad inferences; I would say that this is not possible – people must contextualise data in some way, or they will simply not retain it. Also, the fact that people do develop incorrect information or knowledge does not invalidate the hierarchy, and when they later get more or different data or information, at that point they will alter the information or knowledge with new inferences.

The DIKW hierarchy is a valuable way of assessing how much use an individual has made of different datum. The highest level, Wisdom, is little used because of the difficulties in quantifying anything so subjective. However, the creation of information from data and knowledge from information will be used in the remainder of this thesis to help describe how both individuals and groups use knowledge in order to collaborate.

Using the idea that 'understanding' provides the transition between each of the states represented in the DIKW model, the definition of knowledge for use in this thesis is:

> *Knowledge* is an understanding of how to use information to solve a problem.

4.2 Knowledge Artefacts

This section introduces a particular way of describing knowledge that allows the manipulation of it in a way very similar to as if it had tangible properties. The benefit of this it twofold: first, it allows the bounding of particular pieces of knowledge so that they can be assessed for their purpose and usefulness; and, second, it helps to realise a structure for knowledge that could be supported by technology.

Stahl (2006) suggests that knowledge can be viewed as a type of artefact in group work. Dealing with knowledge in this way presents us with some new challenges. For example, something physical like a mobile phone would generally be identified as a single artefact and two phones as two artefacts, but with intangibles such as knowledge it is harder to identify this boundary. It is also important to note that there is a hierarchical nature to knowledge, where some knowledge artefacts exist at a meta-level to groups of others, providing such things as organizational information about them. Practically, however, group knowledge is a resource that is used to inform other activities. In the model presented in Chapter 5 of this thesis, the development of group-owned knowledge artefacts supports the understanding of the set task and its sub-division into well-bounded, clearly understood sub-tasks.

Artefacts are usually adopted into a group through a negotiation process; a concept that has also been extended to include knowledge and information (Stahl and Hermann, 1999). Olson and Olson (2001) saw this process as one of *clarification*, and split clarification activities according to whether the group was clarifying issues, goals or other activities. The negotiation process can lead to the adaptation of artefacts, as well as their adoption (Dourish, 2003), and this process leads to there being a difference between the artefact proposed by an individual and what is finally used by the group. The nature of this adaptation depends upon the physical adaptability of the artefact; if a tangible artefact is not easily adaptable, a group can adapt their understanding of it instead, so that novel uses develop as group emergent knowledge.

When work groups are faced with complex or highly unstructured tasks, they often organize them into sub-tasks so that they can both be better understood and the work suitably divided between group members. Some models require this task division to be split down into sub-tasks that can be performed as a single action and are sometimes termed *unit tasks* (Card et al., 1983). The level of granularity that is modelled in Chapter 5 is higher than this, although harder to define precisely. The problem solving groups that are studied in this thesis are looking for a level of task division that means each sub-task can be associated with a group-defined sub-goal that the group believes would help them achieve their overall goal. Therefore, the sub-task must have a specific objective, even if the group do not clearly understand how to achieve this objective either. The process then iterates until they identify a sub-task for which they can identify and allocate sufficient well-defined activities to achieve the sub-goal.

Vogel et al. (2004) considered how collections of knowledge as objects could be used to support tasks in distributed groups, both synchronously and asynchronously. They see the problem of supporting collaboration as one of providing better-structured information for their distributed collaborators. They developed a prototype system, *ActivityExplorer*, which attempted to structure information for the group's members. The inspiration for this was to consider the benefits of e-mail (lightweight, low cost and ad hoc), but to reinvent these characteristics in an activity-centric paradigm.

This approach is representative of many solutions for distributed groups, because in studying distributed groups it is easier for the communication medium to double as a capture mechanism that can be manipulated to support the group, because the overhead of that medium already exists. In co-located settings, this presents a different problem, because capturing the information built in the meeting is an extra group activity.

Hill and Gutwin (2004) produced a toolkit to support awareness in synchronous distributed groups. The rationale for this, in their words, was that 'group awareness - the up-to-the-moment understanding of others' activities in a shared space - is a crucial part of successful collaboration'. In the work reported in their paper (in common with many groupware studies of distributed groups), what they were trying to achieve was to replicate some of the tacit ways in which co-located group members obliviously communicate. The work relates to the Vogel et al. (2004) study, as the writers try to take the benefits of e-mail to develop into a more structured support strategy for collaborative work.

Looking at the ways in which support tools for distributed groups are developed can help us reflect upon what is important within co-located groups. In distributed groupware, developers are continually trying to find ways to replicate the awareness of and communication about shared knowledge. In co-located groups, there are no fundamental technological barriers to either awareness or communication, but there remains an opportunity to support these processes more effectively.

Carroll et al. (1991) identified that there is a cyclic relationship between tasks and artefacts (figure 4.2). Observing and analysing tasks provides new requirements for artefacts, whereas the introduction of novel artefacts stimulates new ways of approaching tasks. The task-artefact cycle has been widely used to inform and support the development of tangible artefacts.

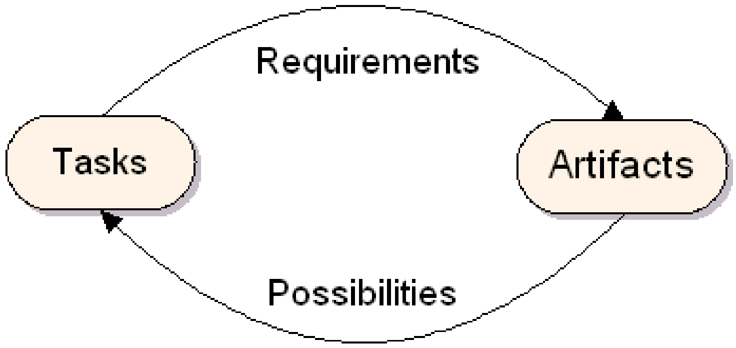

Figure 4.2. Task-artefact cycle, from Carroll et al. (1991)

The task-artefact cycle is also a useful model for describing shorter-term low-level interactions, particularly when thinking of knowledge in Stahl's (2006) terms, as usable and identifiable artefacts. In this case, trying to break down a complex task will lead a group to need to generate knowledge artefacts; these knowledge artefacts then give the group possibilities for solving task-related problems and completing parts of their task; in doing so, this will generate requirements for further shared knowledge to be developed; and so the cycle continues until the task is fully complete. In Chapter 5, this low-level development cycle of knowledge artefacts is used to develop a more detailed model of how complex tasks are broken down by problem-solving groups into more manageable activities.

4.3 Representations of Knowledge Artefacts

The thesis has already identified that one problem in making use of knowledge artefacts is in trying to understand the boundary of an artefact when it has no tangible form. A solution to this is to define knowledge artefacts according to their representations. By this, it is meant that the knowledge artefact can be bounded by the physical artefact that group members use to gather a certain amount of information together and turn into shared group knowledge.

For example, a common device for disseminating and discussing group-relevant information is a shared whiteboard. During a discussion group members can build a representation of many pieces of information on the whiteboard and then discuss further how these pieces of information interrelate, until they have developed a shared meaning for what is represented by the writing on the whiteboard. What is on the whiteboard is now a tangible representation of a knowledge artefact.

Kientz et al. (2006) studied home-based therapy teams supporting autistic children. The researchers supported the therapy team by developing a system called *Abaris*, which is a system intended to support data-based decision making. This Group Decision Support System (GDSS) relies upon the capture and indexing of video data from the home-based sessions, which is then turned into various types of information about the meetings. Team members then have the option to review either aspects of the raw video, or representations made by the system.

In this study, the researchers identified the following representations as artefacts used in group decision making:

1. *Graphs showing a child's performance over time*. These are built from a collection of therapists' data from specific repeatable tests.

2. *Videos of therapy sessions*. The therapists use a fixed camera to record the sessions.

3. *Data sheets from individual sessions*. The non-aggregated data, shown raw as collected by therapists at every session.

4. *Therapy samples from sessions*. Examples of physical artefacts created during a session, such as handwriting or artwork.

5. *Re-enactments of a child performing a skill*. During meetings, therapists may record children attempting to recreate specific aspects of therapy sessions.

6. *Memory of those present at a team meeting*. Therapists recount the events of a weekly session, to help give context to automatically collected data.

7. *Observations from external sources*. Parents at therapy meetings may introduce information drawn from the child's school, or other third parties, which they feel is important for the therapist to be aware of.

8. *Notes written by therapists after sessions and meetings*. After each therapy session, therapists write up their own account of the session.

This study is particularly interesting as it highlights the difficulty in distinguishing between group information and group knowledge. The boundary between the two, as the thesis has shown here, is difficult to establish as an individual; at a group level, this becomes more difficult to identify, both for group members and external observers, because only explicitly stated common ground is visible. Behind this, only inferences can be made about further shared understanding, and whether the group really has identified shared knowledge from its pool of shared information.

Using a representation of information to bound a group knowledge artefact is a very useful way of modularising knowledge, especially if our aim is to develop systems that contain knowledge objects. However, there are also potential problems with this approach. Here the thesis suggests four such problems.

1. *Does the represented knowledge artefact answer a 'how?' question?* By this, it is meant that many things in group work have a tangible representation; some are brought fully-formed to the group and others are constructed by them. However, many of these things represent something other than a knowledge artefact.

2. *Is there anything missing from the representation?* The representation may hold only some of the information required for a useful knowledge artefact. For example, the knowledge artefact might be constructed from a number of representations and the awareness that together they answer a 'how?' question.

3. *Is there anything in the representation that is outside the boundary of the knowledge artefact?* The opposite of point 2 is also clearly possible. Using the earlier example of the shared whiteboard, this could be used to gather information that is organised to answer several 'how?' questions. It could also be that many pieces of information are gathered on a whiteboard and during the group's discussion some of these are used to construct a shared knowledge artefact. If all the information remains on the whiteboard, then as a whole it cannot be said to be a clear representation of that knowledge artefact. Significantly, the knowledge artefact is in fact a pairing of the relevant pieces of information represented plus the group's shared awareness of which pieces are relevant.

4. *Is the information used in the representation also relevant to other knowledge?* This problem with using representations as an externalisation of knowledge artefacts is in fixing pieces of information to a particular piece of knowledge. In Chapter 5, analysis is presented to explain how problem solving groups break down Rittel and Webber's (1973) 'wicked problems' into manageable activities (see also this chapter, section 4). In doing this, groups have to work with an incomplete picture of what is required to solve their problem and, therefore, one of their important needs appears to be that they have a ready pool of shared information in order to construct shared knowledge. An over-reliance on using representations to bound information may hinder a group as it tries to reason through uncertainty.

The common thread in these problems with information and knowledge representations is that awareness is an important part of both constructing knowledge and defining the boundary for what group members would agree to be a single knowledge artefact. The need for this awareness of constructed knowledge is also important for how well a group can collaborate. Latecomers to a meeting, for example, or even group members not in a particular subgroup may not have the shared awareness for represented information to have the same meaning as the group members that constructed the knowledge.

4.4 Developing Group-level DIKW

To understand how groups develop shared knowledge, the thesis takes the DIKW chain and develops what it means for each of the phases within it to be represented at a group level. The mapping of individuals' DIKW chains to an equivalent that exists at group level shares all the complexities and problems that were highlighted in other group-level constructs in Chapter 3.

4.4.1 Group Data

In a group context, there is very little that is shared between group members that can be identified only as data, i.e., something that has no inherent meaning. Any data that is introduced to the group by a group member must be contextualised in some way by the group, otherwise there is no reason to adopt it.

Therefore, group data should be seen as *emergent* group data, i.e., something that the group creates during either shared taskwork or shared teamwork activities. Even in this context, group data should be seen as a transient state as emergent group data that is not contextualised very quickly will be lost, as it is not possible for a group to retain something as a shared representation when that representation is completely without context.

The notion of the emergence of group data does allow us to consider more carefully how groups break down complex, unstructured tasks into manageable and schedulable activities. The emergent data are building blocks from which new understanding and structure can be built.

Also, this shows that in the mapping between the various group members' individual DIKW pyramids will initially be quite weak, and items that might reasonably be described at one level for the individual may only exist at a lower level for the group. By this, it is meant that something an individual has contextualised as information, if it is visible to other group members but not fully explained, may only exist as data to them.

4.4.2 Group Information

There are two ways in which groups create shared information artefacts. The first way is by developing emergent group data, finding a way of understanding it and giving it a context. The second way is by a group member introducing some information to the group, which the other group members choose to adopt. These two ways of developing information are interesting because they involve different barriers, or different boundaries that need to be crossed for the information to successfully become a group-owned artefact.

For group information to be derived from emergent group data the group needs to identify and complete an activity where they determine what the shared understanding of the data is, within the overall context of the group. Looking back at the jigsaw-based study reported in Chapter 3, there are examples of such a process taking place.

For example, when the groups began to complete the jigsaw puzzle they (i.e. members of both groups) emptied the box of pieces onto a table. As they are negotiating how to complete the puzzle, each group's members are turning pieces face up and sometimes collecting a few pieces together according to colour, or other things that occur to them as they're doing it. What they are achieving by this is the creation of group emergent data, simply by handling the shared physical artefacts.

The activity that turns this new group data into information is a negotiation process where each group's members discuss what value this new data has in their collaborative attempt to complete the task. In parallel, or at least interwoven with this, the same data leads to the creation of individual information and knowledge. Using the same observation point in the jigsaw-based study, group members are individually turning the group emergent data into personal strategies for how the group will complete the task. However, as they only have direct control over their own actions, they must turn this individually held knowledge into group knowledge by persuading the other group members that their strategy is the one that the group should adopt.

For group information to be adopted from an individual's information, one of the group members needs to present something to the group for them to consider its relevance. The group member presenting some of their individually held information may have higher-level notions of what the information means to them, i.e., the individual information may be integral to something the individual regards as knowledge or wisdom in terms of the DIKW definitions. However, during the adoption activity, the group may change the information, i.e., they may discuss, negotiate and change the way in which the underlying data is understood before they adopt the information as a group-level artefact. If they do this, then of course this has a knock-on effect on the interpretation of the higher-level structures, knowledge and wisdom.

Another effect of sharing information into the group is *informational influence* (Forsyth, 1999), which is defined as 'social influence that results from discovering new information about a situation by observing others' responses'. This is an effect that can have both positive and negative outcomes. A (potentially) positive outcome of informational influence is that the group develops a workable way of collaborating together, thereby developing the necessary behavioural norms that the thesis described in Chapter 2; additionally, this helps to move a group through the development phases that it needs to be effective (e.g., Tuckman, 1965). However, there is also the (potentially) negative outcome that the informational influence will lead to groupthink (Janis, 1982). Both these effects are qualified by the word potentially, as the possible outcome has a great deal to do with the individuals that comprise the group.

Shared group information for distributed groups has been an important subject for CSCW, and has generally been referred to by the term Common Information Space (CIS). Schmidt and Bannon (1992) described the common information space as 'maintaining a central archive of organizational information with some level of shared agreement as to the meaning of this information (locally constructed), despite the marked differences concerning the origins and context of these information items'. This matches well with the idea of group knowledge being represented as artefacts, as Schmidt and Bannon (ibid) emphasise the importance of a shared agreement of meaning to unlock the potential of shared information. The development of the shared meaning, on a smaller scale, is the know-how that this thesis terms as group knowledge. Fields et al. (2005) observed the development of this know-how in a study of air traffic controllers, describing the process as a 'coordination of representations'.

4.4.3 Group Knowledge

In the Ackoff and Zeleny hierarchies of DIKW, knowledge is the 'application' of information. Also, in Ackoff's original hierarchy, there existed the extra level called *understanding*. One interpretation of the *de facto* development of the DIKW hierarchy is that understanding and knowledge in Ackoff's terms have merged into the umbrella term of *knowledge*.

This means that what the thesis terms as *group knowledge* should enable a group to answer 'how' and 'why' questions which are pertinent to their group information.

Krauss and Fussell (1990) use the term *mutual knowledge problem* to define the difficulty that people who want to communicate must overcome:

> 'The mutual knowledge problem derives from the assumption that to be understood, speakers must formulate their contributions with an awareness of what their addressee does and does not know.' (p112)

Clark (1996) describes the resolution of this problem as one of establishing and building *common ground*, where the common ground between two (or more) people is an understanding of the collection of all the shared cultural and informational reference points that they have between them. They are then able to use this common ground as building blocks and enablers for them to build shared knowledge.

Krauss and Fussell (1990) argue that there are three interrelated sets of mechanisms by which mutual knowledge is established, these are:

> *Direct Knowledge.* These mechanisms depend on personal knowledge of other people, specifically of what particular other people know.
>
> *Category Membership.* This set of mechanisms depend upon individuals belonging to identifiable social categories, and by sharing the same social categories with others, being able to make reasonably accurate inferences about whether other people will already have a shared representation of something.
>
> *Interactional Dynamics.* This set of mechanisms describes how mutual knowledge can be established through the process of interacting. This means that over time, and through interaction, individual knowledge is transformed incrementally into mutual knowledge.

The definition in this thesis of what is meant by *group knowledge* and what Krauss and Fussell (1990) describe as *mutual knowledge* are closely related. The difference is that group knowledge is bound to the task that a group has been formed to undertake. This means that so long as the task is not trivial there will always be an element of uncertainty that will require the group knowledge to be constructed through discourse and actions.

Group knowledge can only be constructed from group information that is applied to specific group activities. The activities in question might be related to taskwork or teamwork, but at least one of these must apply for the activity to have a purpose that group members can relate to.

Any group knowledge retained will be tested against future tasks and may be modified accordingly. This again brings into question the difficulty of clearly identifying the boundary for a group knowledge artefact. Using the DIKW definition of knowledge, it is possible to assert that a single group knowledge artefact is constructed of sufficient shared information to answer a specific ‘How?’ question to the satisfaction of the group’s members. Depending upon the questions that the group needs to answer in order to complete its tasks, these shared knowledge artefacts may overlap in their construction, but should individually have only one purpose.

Therefore, at this point the thesis can revise its earlier definition of knowledge to give a definition of group knowledge:

> *Group Knowledge* is a *shared* understanding of how to use information to solve a problem.

4.4.4 Group Wisdom

The peak of the DIKW hierarchy, *wisdom*, was the most difficult part of the hierarchy to identify clearly at an individual level. Like with the other group-level attributes drawn from individual equivalents, any slight ambiguities at the individual level are magnified and compounded at the group level.

The thesis describes group wisdom as being a shared understanding of the effect of knowledge, once it has been applied to something in the group context. At some level, this could be considered to be a meta-knowledge or a refinement of existing knowledge with respect to some activity. This refinement of knowledge through direct experience also affects what group members take with them and introduce into other groups, meaning that wisdom is an agreed application of knowledge that propagates.

4.5 Group Artefact Adoption

This section discusses the process of how individuals transfer their personal information and knowledge into the group, so that group knowledge artefacts are developed. Later, in Chapter 5, the study analysis is designed look for instances of this process in the reported study and show how they support the breakdown of complex tasks into manageable activities when a group is collaborating.

Artefacts are adopted (or rejected) by the groups through negotiation, followed by a ‘sign-off’. The negotiation process (Figure 4.3) begins with an artefact being introduced to the group by one of its members. At this point, the introducer can be considered to be the sponsor of the artefact, and the discussion begins with them making a case for it. Whether the artefact is tangible or not, the case for the sponsor will be linked to how it progresses a sub-task and how it fits with the overall understanding of the main goal at any given time.

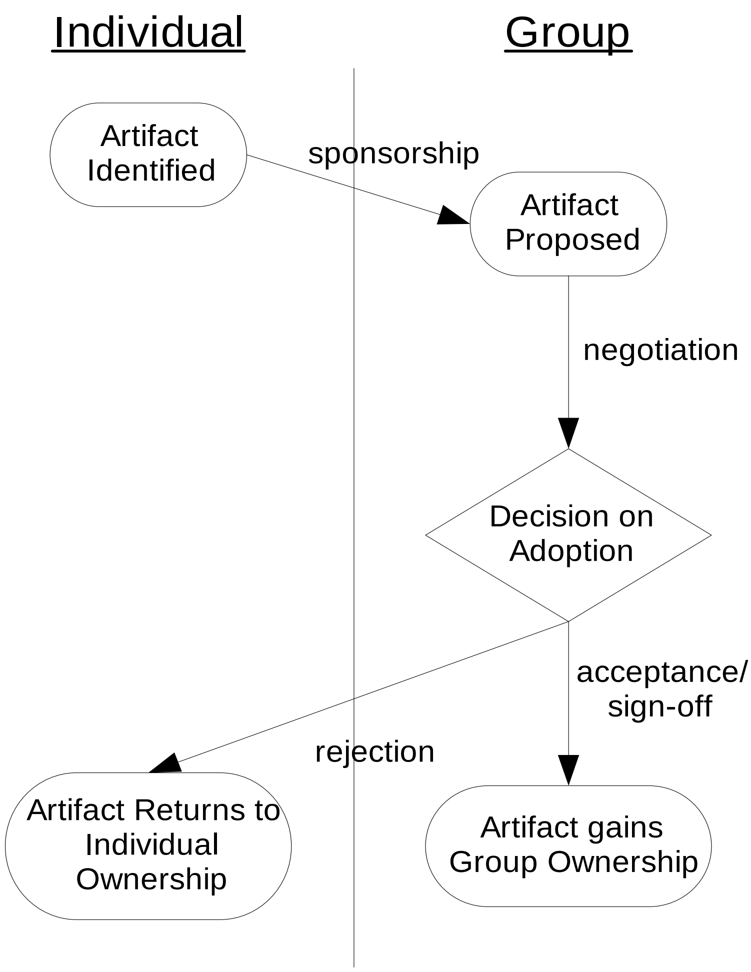

Figure 4.3. The negotiation process for group artefact adoption, showing how the artefact's in-group ownership shifts between the individual and group levels

How well the proposal meets the needs of the group depends on the common ground (Clark, 1996) that the group members can draw upon to understand a shared perspective. So, in early group meetings these negotiation processes will drive the group towards shared understanding, which in itself is the negotiation and adoption of group knowledge. Later, these knowledge artefacts will help establish group norms as part of the group members' shared history (Feldman, 1984), which limit the appropriation of further artefacts to within defined boundaries.

The negotiation process that leads to the group deciding whether or not to adopt the artefact can also lead to the generation of further knowledge artefacts, which are also, implicitly or explicitly, proposed and considered for adoption. This multi-threading is partly responsible for the difficulty that groups have in seeing this process as they perform it. Once group norms begin to be established, the negotiation processes become quicker and more focused, because fewer concurrent negotiations are required to reach a point of common understanding and make a decision.

When the group makes a positive decision to adopt an artefact, the individual has to relinquish control of it. It is no longer theirs to shape in terms of content or use, without reference to the group. By contrast, if the group does not adopt an artefact, then its ownership is returned to the individual; however, even when an artefact is rejected by the group and returned to individual ownership, it has still passed through the negotiation process and so could still have changed. Often the same artefacts, tangible or otherwise, are re-presented to the group at other times, when the sponsor thinks that something has changed in the task understanding to justify another attempt.

Robinson (1993), in discussing the appropriation of collaborative artefacts into groups, stated that they were successful when they were characterized by the dual modality of double level language. He claimed that collaborative artefacts should provide implicit communication, where it is the medium for communication and explicit communication, where it provides representations that are recognized within the context of the work being undertaken.

4.6 Complex Problems

The thesis's reason for understanding how group knowledge is developed stems from a desire to better understand how problem solving groups work through the complexity and uncertainty of their work. This section defines what is meant in this work by complexity and the problems that it presents, drawing particularly from the work of Rittel and Webber (1973, reprinted 1984) who introduced the idea of 'wicked problems'.

Rittel and Webber's work was drawn from the field of urban planning, but their issues with the complexity in urban planning have since been used widely to express the difficulties with complexity in problem solving. Ritchey (2008) breaks down the original work into the following ten criteria for a wicked problem:

1. *There is no definite formulation of a wicked problem.* By this, it is meant that the information required to solve the wicked problem depends upon one's idea of a solution. By extension therefore, all the information for all possible solutions would be required in advance in order to formulate the problem.

   This is a characteristic of many problems that groups have to solve, even those that are far more routine than the ones described as 'wicked'. Our interpretation of how groups address this is described in Chapter 5.

2. *Wicked problems have no stopping rules*. An absence of stopping rules does not imply that the project being described never stops. What this criterion implies is that there is never a set of rules by which the full, complete and best solution to the problem can be said to have been met. Instead, the group will either run out of resource or deem a solution to be satisfactory.

   This is not such a big problem for many groups as other criterion, such as time available, often override even the simplest of tasks and lead to satisficing (Simon, 1957) compromises. There are very few tasks that are so trivial that there is an obvious best solution.

3. *Solutions to wicked problems are not right or wrong, but better or worse*. This simply means that the quality of any particular solution is down to the judgement of the project's stakeholders, and they will value any given solution according to that judgement.

   This observation illustrates the value of stakeholder involvement throughout a complex task, assuming the success of the project depends upon the stakeholders' opinion of the final outcome.

4. *There is no immediate and no ultimate test of a solution to a wicked problem*. Initially, this appears to contradict the third criterion, as the stakeholder's opinion is a test of the solution. However, what is really being said here is that the true success or failure of a solution becomes apparent over time and through use within its field of application.

   This is again true of many problem areas outside that of urban planning and is perhaps a reason that iterative development of problems solutions is so commonplace. It is the reason that the task-artefact cycle (Carroll et al., 1991) was originally proposed and explains the need to understand the possibility of emergent properties after implementation, which may be beneficial or may create another problem to solve.

5. *Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly*. This is a bold statement, especially when considering that it is drawn from 1970s urban planning. The reality is that the solutions to many problems, even safety-critical problems, are drawn from an understanding of previous errors.

   What I believe the authors are really trying to say by establishing this criterion for wicked problems is that there are consequences for learning iteratively. These consequences maybe severe on the solution's users, but also on the problem solvers – a poor solution can lead to further and ever-more-complex wicked problems to solve.

6. *Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan*. The consequence of this is that it is impossible to show

that all solutions to a wicked problem have been identified and considered before one particular solution has been chosen.

This criterion and the previous one highlight a particular issue for groups that are formed to solve complex, unstructured problems. There is a tension between finding a solution that is initially identified as being a satisficing solution and finding a number of alternatives that the group may be able to judge as potentially better or worse. The greater the consequence of any errors, the more alternatives the group are likely to have to reason through before implementation.

7. *Every wicked problem is essentially unique*. The point of this criterion for the authors was that those trying to solve a wicked problem should not try to characterise it into some previously-understood class of problem too early.

   Here I agree with the observation, but disagree with the suggested approach. The observation that every wicked problem is essentially unique I would extend to say that any instance of a group attempting to collaboratively solve a problem is unique. However, to suggest holding back any attempt to classify a problem, or problem-solving instance, is a mistake. There are two fundamental reasons for believing this to be so: (1) it makes the cognitive load of solving the problem too high, by suggesting that there is nothing to relate a problem to any that have been previously attempted; and, (2) it underplays the significance of group members' prior experience in the process of problem solving. These issues are dealt with in this thesis from Chapter 6 onwards.

8. *Every wicked problem can be considered to be a symptom of another [wicked] problem*. This criterion of wicked problems illustrates both the difficulty of identifying the interrelatedness of problems and the difficulty of identifying the appropriate boundary for the problem to be addressed.

   Ackoff (1974) made a similar point when he described the interrelatedness of all problems as a 'mess'. The mess in question is the difficulty in unpicking different problems from each other, so that a particular problem can be identified and solved. This problem at the meta-level described by Ackoff is intractable, but groups continually do find ways of determining an achievable problem boundary.

   How groups look to identify the boundary of a complex, unstructured problem is analysed and reported on from the study introduced in Chapter 5.

9. *The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution*. The point that this criterion tries to make is that wicked problems remain wicked problems even when they have to some extent been resolved by an implemented solution. At any given time, the current understanding of that problem is at some level bound to the implemented solution.

This is another important point taken into the study reported in Chapter 5.

10. *[With wicked problems,] the planner has no right to be wrong*. Taken from Rittel and Webber's domain of urban planning, this criterion tells us that solutions delivered to the 'real world' cannot be bad solutions because they have a direct impact upon people's lives. This essentially means that their definition of a wicked problem is partially that the problem, as well as being complex, has some real world impact.

    The implication of this is that in laboratory settings, for example, the researcher can afford to be wrong as there is no direct impact upon the general public. I would say that this is true so long as the researcher realizes they are wrong; otherwise, with any problem the problem-solver has no right to be wrong, as problems, wicked or otherwise, are interrelated and the effect of one bad solution may be felt across many future problems.

Rittel and Webber (1973) claim that in wicked problems, or those that are essentially unique or ill defined, rebounding the issues is an essential part of the negotiation process. This thesis also considers the reverse influence of how rebounding the task affects the adoption of knowledge artefacts. They also see problems – at least in their domain – as a black and white distinction between 'wicked' problems that possessed the criteria described above, or 'tame' problems for those that did not. This thesis shows that task complexity, and problem solving tasks within that, form a continuum between the tame and the wicked.

The criteria that describe wicked problems leads to the question 'How do groups break down complex and unstructured tasks into manageable and purposeful activities?' Wicked problems clearly exist, but they are rarely intractable to the point that some progress towards a solution cannot be made. The study in Chapter 5 addresses this question.

4.7 Conclusion

This chapter has discussed Stahl's (2006) concept of viewing knowledge as artefacts. In the wider context, it has looked at what people understand to be knowledge and artefacts, and why putting the two together provides a very useful building block for understanding and supporting collaborative group work.

It has also reviewed Rittel and Webber's (1973) criteria for their description of 'wicked problems' and discussed how these relate to a more general set of complex and unstructured tasks, drawing upon the literature review in Chapter 2 to further support the idea that the complexity of any given task lies upon a continuum, but in developing an understanding of that task it becomes a collection of smaller tasks that tend towards the 'tame' end of the continuum.

In the next chapter, a study is introduced where these concepts are used to analyse and understand a series of linked, co-located group meetings. From this, an analysis model for describing how complex or unstructured tasks are broken down into manageable activities is proposed.

5 A Taskwork Model

> If you do not feel yourself growing in your work and your life broadening and deepening, if your task is not a perpetual tonic to you, you have not found your place
>
> Orison Swett Marden, 19^{th} Century American writer

This chapter introduces a second study, which was designed to be representative of the type of problem-solving co-located meetings that take place when group members that are primarily distributed for their work get together. This particular profile of work is important when considering co-located groups that have complex tasks to resolve; the reason for this is that the more complex a task is, the less likely that it is going to be resolved in a single co-located session.

The study is intended to realistically model real life situations, where groups meet to disseminate information, develop new, shared knowledge and identify and distribute new activities. An example of this type of recurring meetings can be found in the homecare sector (Orre and Middup, 2006), where carers meetings are designed to give support to a complex problem that meets many of the criteria of Rittel and Webber's (1973) wicked problems and is essentially endless.

In the co-located meetings, such groups have to balance their time between effectively progressing co-located work, building shared group knowledge and scheduling work for the larger periods of time that the group works in a distributed setting. Bellotti et al. (2004) have previously shown that individual task prioritization in groups requires great effort and in this study it was observed that this is strongly coupled with task progression in problem solving work groups.

The successful progression of work group tasks is aided by specific activity-focused periods, whereby a group member communicates to the rest of the group something that strongly develops either the team or the task. These acts of 'dominance' are fleeting and sufficiently subtle so that any team member might reasonably be expected to dominate either the team or the task at some point.

From the observations of this study, a model is presented that has been developed to show the key phases of taskwork for co-located problem-solving groups. A report of this model and its development has been previously published and presented at the Sixth International Workshop on TAsk MOdels and DIAgrams (TAMODIA'2007) (Middup and Johnson, 2007).

5.1 Observing Activity-focused Interaction

To observe how co-located work groups used artefacts (both tangible and knowledge-based) to organize their tasks, an empirical study was devised and run. The study involved eight people in two groups of four over a four-week period, with the groups being asked to meet together once each week to report their work, fit this into the task and schedule each member's work for the next week. Using the Poole et al. (2004) classification (described in Chapter 2), this study is based upon both the functional and temporal perspectives.

The group members were all graduate students from the same department of the university campus. They had met previously around the department, but had not worked together in the groupings organized for this study. Aspects of their group work in this study are shown in figures 5.1 and 5.2.

The task the groups were asked to perform was to compile a flora and fauna survey of the university campus. The task was deliberately open-ended, so that team members had to balance the demands of breadth versus depth in their survey, given the time constraint upon them. They were required to produce a poster by the end of the fourth week. To encourage the groups to make their best effort at the task there was a small cash prize offered for the survey considered best by two independent judges.

The two groups shared a number of resources: they both used the same meeting room; they both had individual notebook diaries in which they were asked to record their work schedules in the meetings and their findings and intra-group communications between meetings; finally, they shared the same external environment – both as a location for their survey and as a location to use unspecified external resources.

The principal difference between the groups was that one was asked to support their survey and produce a poster only using pen and paper, whereas the other group was asked to maintain their group records and produce the poster on a computer. There were a number of reasons for introducing this difference: first, it was believed that it would be interesting to see if this affected the tangible artefacts used to gather and present information – for example, would the group developing the poster on the computer be more likely to use high-tech artefacts for gathering information; it was also felt that this might generate different approaches to developing shared group knowledge; second, the study would identify if the different approaches would suggest any differences in the use of space and sub-groups in the co-located meetings.

Figure 5.1. Group One in discussion

Both groups' members had individual diaries, in which they were asked to record the work that they undertook during the week in between meetings, as well as any communication with other group members relating to the survey.

At the beginning of each meeting, the room was always laid out in the same way for both groups, including the distribution of resources. There was a central table around which the chairs were initially placed; the other resources were distributed around the room, the group record (notepad or laptop) on a desk at one end of the room and the resources to make a poster (desktop, or pens/paper/scissors/glue) on another desk at the other end of the room.

The layout of the room gave the group members three distinct areas in which they could work. In the middle of the room they had their meeting area, and at the two ends they had resource areas. The resource areas had the same purposes for both groups, but the artefacts provided were very different. The first resource area contained everything needed to produce the poster: for the first group this was pens, paper, scissors, tape, etc. and for the second group, this was a desktop computer with PowerPoint installed. The second resource area provided everything needed to produce the group report: for the first group, this was their report book and a pen, and for the second group this was a laptop computer with their group report file on the desktop. The purpose of defining these spaces was to observe how the group divided its members according to the sub-tasks they wanted to work on at any given time.

There was no restriction placed upon group members as to whether, when or by what means they could communicate between the fixed meetings. If they felt that they required extra meetings, then this was allowed too. It was felt that a mixture of compulsory meeting with optional extra gatherings, if necessary, was a representative model for the way many ‘real world’ groups interact. In fact, only one extra meeting was requested by one group, and this was during the last week of the study when they preferred to split their work for poster production over two days, into planning and output sessions.

Normally, communication between meetings was limited to e-mails or unplanned face-to-face contact (i.e., bumping into each other on campus). Group members recorded these interactions in their individual diaries and copies of e-mails were forwarded to the researchers. Video recordings were made of all the scheduled co-located meetings, using two fixed cameras and additional cameras or computer output capture, as appropriate, to capture a quad mixed image. The extra unplanned group meeting was also captured in this way.

Figure 5.2. Group Two developing their poster

The verbal and non-verbal communication of group members in the co-located meetings was encoded using SYMLOG, a system for the multiple-level observation of groups devised by Bales and Cohen (1979). The system enables an observer to construct messages that describe group behaviour. One feature of SYMLOG is that it separates the behaviour of the group members towards the target of each interaction from their behaviour towards the subject of that interaction, a distinction that was used to analyse interactions specific to taskwork and task development.

Encoded interactions in SYMLOG have a message built from a number of mnemonics, providing the observer a consistent syntax with which interactions can be compared, and patterns of communication identified. The three middle-week meetings for each group were analysed using parts of this tool. The reason for omitting the initial meeting is that the groups had no data to work with, so they were merely a start up and plan exercise. The reason for omitting the final meeting is that the group had no further sub-tasks or events to plan. The remaining meetings are a more accurate model for ongoing regular co-located meetings in workplaces.

Observers, either in real time, or later from video analysis, score SYMLOG interactions. Because of this design, the coding system has a high reliance upon mnemonics, so that speedy encoding is possible for those that choose to perform it in real time. As the study reported here was laboratory-based, the interaction scoring could be made from digitised video recordings.

The benefit for this study is that SYMLOG allows the observer to encode two different aspects of communication behaviour for each interaction. The advantage of using this coding system is that it captures the underlying shifts of behaviour that take place very quickly in human-human interaction.

The two parts of the SYMLOG message capture the attitude of the person initiating the interaction, firstly towards the recipient of the communication and secondly towards the subject of the communication. The message also uses a three letter mnemonic to represent each group member; these mnemonics have been retained in the discussion section of this paper to maintain the anonymity of the participants, but allow dialogue to be presented in a meaningful way that keeps the observed interactions intact.

The recipient of the communication in the observed meetings was either a specific individual or the whole group. Each communication with an individual or group was rated with an interaction type (explained below) that denoted their intention or 'mood' towards the recipient. This intention need only be for that phase of communication, and not necessarily represent any prevailing moods within the group interactions.

The subject of the communication could be a range of things: it might be another person, within or outside the group; it might be the task; it might be an artefact, within or outside the meeting room; or, it might be something less tangible, like a feeling. The interaction type that denotes the intention towards the subject of the communication can often be quite different than that for the recipient.

The letters recorded to denote the interaction type give the message a place in a three-dimensional space, drawn from three axes (as shown in figure 5.3) – the absence of a letter from any pair showing that the message is neutral in this respect and lies in the middle of that axis. The first axis determines whether the interaction is positive/friendly ("P") or negative/unfriendly ("N"). The second axis determines whether the interaction is upward/dominant ("U") or downward/submissive ("D"). The third axis determines whether the interaction is backward/emotionally expressive ("B") or forward/instrumentally controlled ("F").

An example of the difference in coding interaction types for the recipient of the communication would be that informing the group of one's survey data might be presented in a friendly way and be coded "P"; instructing another group member, or the group as a whole, to report might still be friendly, but could be said to be dominant towards the recipient and would be coded "UP"; asking the group an open question, in an admission of needing their help, could still be friendly but submissive and would be coded "DP".

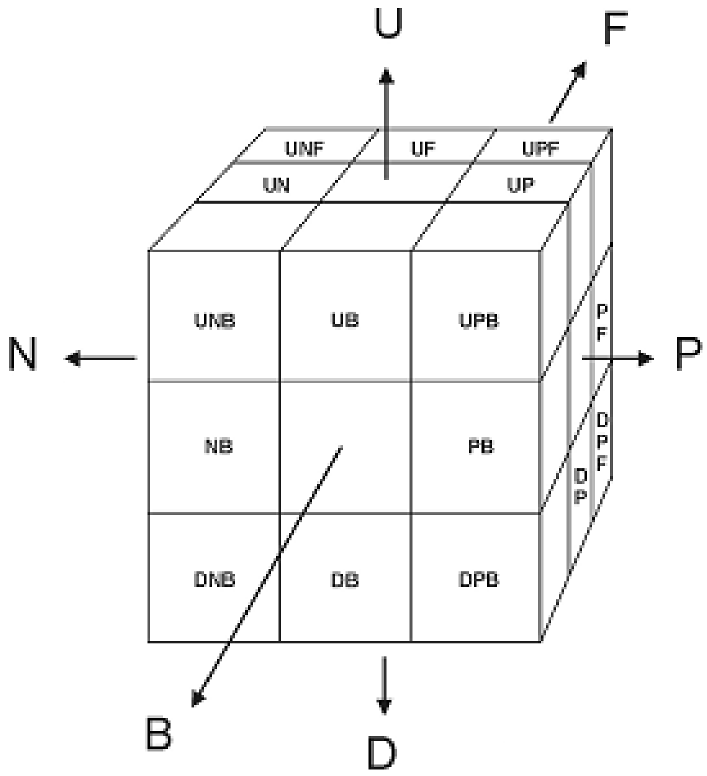

Figure 5.3. SYMLOG 3D Interaction Space, from Bales and Cohen (1979)

When coding the interaction type for the subject of the communication, particular emphasis was placed upon noting whether 'dominance' towards the task (to use the SYMLOG terminology) could be observed if the task was the subject of the communication. This thesis defines dominance towards the task as being communications that state a clear understanding of the task that has not been previously expressed by the group. The reason that these interactions are particularly important is that they have a particular focus on the activities necessary to complete the main task and these activity-focussed interactions appear to be key points in this process. The full structure of the SYMLOG interaction messages is described in table 5.1. Examples of these messages are presented in the worked example section of this chapter.

Message part	*Description*
Time	The time in the meeting that the message is passed between group members. In this study, times were marked to the nearest quarter of a minute.
Who acts	Each group member is given a representative mnemonic. The mnemonic of the person sending the message is recorded here.
Toward whom	The group member or members (GRP is used to indicate the whole group) toward whom the message is sent.
Act/Non	ACT indicates an overt act towards the recipient, intended to carry a message. NON indicates that it was unintentional.
Direction (1)	This is the combination of letters that determine the 'mood' of the message with respect to the *recipient*, using the three-dimensional space shown in figure 5.3.
Description	A brief natural language description of the message.
Pro/Con	This captures whether the message constructor (i.e. 'who acts') is in favour of (PRO) or against (CON) the subject of the message. In this thesis, this aspect of the SYMLOG coding has been interpreted as a high-level indicator of whether the message constructor has a positive or negative attitude to the subject of the message.
Direction (2)	This is the combination of letters that determine the 'mood' of the message with respect to the *subject*, using the three-dimensional space shown in figure 5.3.
Image Level	In this thesis, this aspect of the SYMLOG message is taken to mean the subject of the message. Options here are SEL (for 'self'); a mnemonic that represents one of the other group members; GRP to describe the group as a whole; SIT (for 'situation') represents messages where the subject is the task; and, SOC (for 'society') represents subjects outside the immediate group.

Table 5.1. SYMLOG Interaction message parts

In making this coding, an interesting recurring pattern was discovered in the encoded meetings that showed specific periods of activity-focused interaction. Analysing the communication instances when the group's task was the subject of the interaction and the target was one, some or all of the other group members identified this pattern. The pattern that recurred was one where a group member had a brief period of clear understanding about part of the task, which they communicated to one or more other group members. Whenever this type of interaction was observed, the group made significant developments in their work towards task completion.

These activity-focussed interactions followed the previously discussed method of negotiating knowledge into groups. The clear idea introduced by a group member was rarely accepted without negotiation and even more rarely became a shared idea without being transformed in some way during the negotiation; however, each of these activity-focussed interactions gave the group members direction that they could use to unlock the complexity of their task.

The activity-focused interactions pushed the group work between a number of distinct states that gradually broke down the original task into something more manageable. The relationship between these states and interactions forms the basis of the taskwork model that is described in the following sections of this chapter.

The drivers for the activity-focused interactions that push the group between states are the artefacts that they use to address the tasks and this in turn shapes the use of physical artefacts, as well as generating new group knowledge artefacts. This low-level, quick looping of the task-artefact cycle (Carroll et al., 1991) is supported by continual artefact negotiation within the group.

5.2 A Taskwork Model

The data from the flora and fauna study was analysed to produce a taskwork model (Figure 5.4), which explains the behaviours and activities that take place in low-level group work. It models the interactions that co-located problem-solving work groups use to understand and complete tasks. Tasks are frequently carried out with various levels of interleaving and interruption (Johnson et al., 2003) and the task of structuring a group's work is no exception. This model restructures the complexity into a series of recurring states, so that it can be better understood. Each of the states in the model represents a key phase of group interaction, through which the group gradually understands and completes their original unstructured, complex task.

The periods of activity-focused interaction that were observed progress the group in a particular state and make it necessary for them to shift states, as shown by the arrows in the model, as it becomes necessary to develop their taskwork in a different context.

The model identifies six key phases within group taskwork that enable the process of complex task breakdown to take place. Each of these can be supported by awareness of a group's artefact adoption (of both tangible and knowledge-based artefacts) and how these in turn drive activity-focused interaction. The thesis now describes each of these phases in turn, and provides evidence from the study for their existence and of the transitions between them.

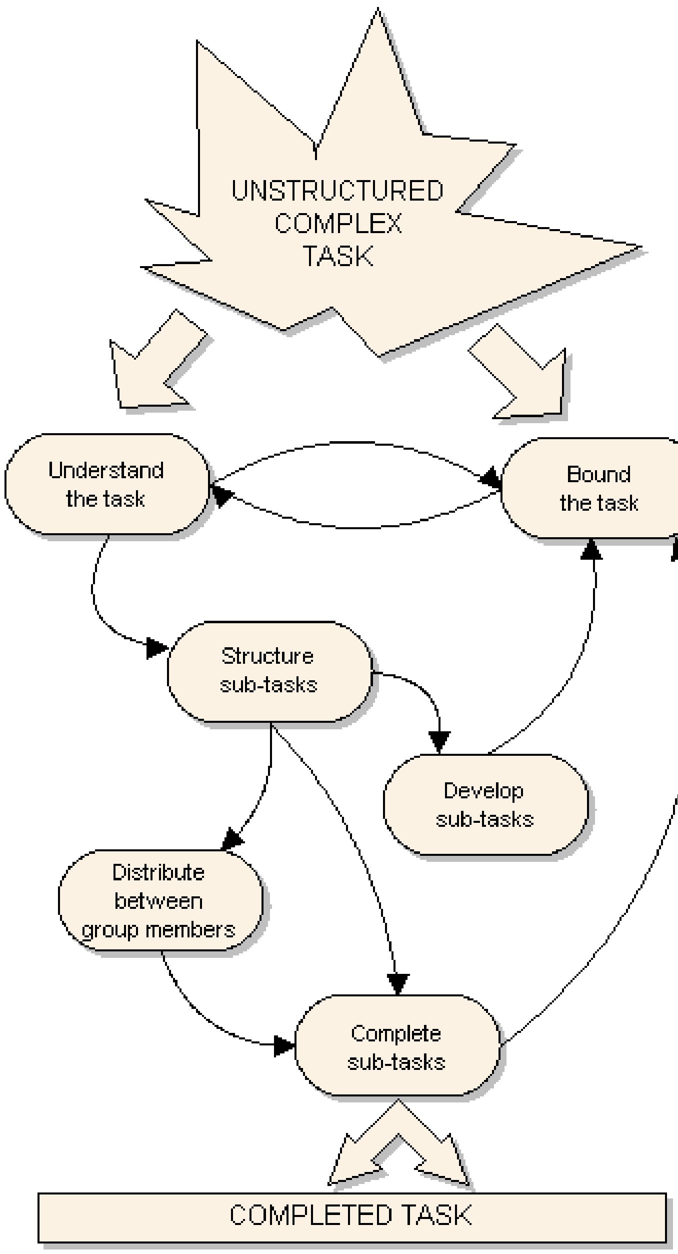

Figure 5.4. The Taskwork Model, showing the interactions required to understand and complete a complex, unstructured task.

Understanding the task.

This is usually the first problem a new group needs to face, where a complex task needs to be assessed and group members contribute what they think they understand about it.

For the flora and fauna survey, both groups first tried to identify skills that they had within the group that might help them progress the task. In terms of artefact negotiation and adoption, the acceptance that someone has a potentially useful skill becomes a group knowledge artefact. The negotiation process involves not only a group acceptance that one of their members has a particular skill, but also that it is relevant and useful to the task and so their perceived understanding of the task increases.

For example, in the study, one of the groups had a member who said that he had previous experience of surveying trees (on a work placement, some years before). The other group members pressed him on exactly what his previous experiences was, and how they might be able to incorporate it into their survey. At the point of this disclosure, the group were still not clear about exactly what they were going to survey, and they used this information to aid that discussion.

At some point the group members become aware that their understanding of the task has increased to a level where they need to use the new understanding. This is the point at which they shift state with a period of activity-focused interaction, with one or more group members deliberately changing the focus of the group to identify sub-tasks or consider the main task boundary.

This phase was continually revisited in the flora and fauna survey as individual and group knowledge increased, providing new insights into the original requirement. Because none of the participants were experts in flora and fauna, they were forced to continually revise what they knew about extrapolating their observations to the rest of the environment. For example, there is a period early on in the second meeting of one group where a group member, STA, uses his report on his sub-task progress to question the detail that the group is looking for.

> STA – "One question I have is how detailed do we go on bugs?"

The nature of this communication shows how the speaker's interaction with the team and task can have different concurrent moods. To the group, he is submissive but friendly: he is genuinely seeking their opinion and his tone suggests that he appreciates their input. At the same time, however, the speaker is demonstrating control over the task – he doesn't know how to overcome his problem, which is why he is asking the group, but he has developed a clearer understanding of what the problem is, and so is taking personal control of the task development by asking the question.

The impact of this statement on the task development is that the group now has to define part of the task more closely and think about how this affects sub-tasks that they have already identified, as well as potential new ones. It also begins a knowledge artefact adoption cycle. Although it isn't fully formed, the knowledge artefact proposed by STA is an entity containing the group's understanding of their requirement with respect to insects.

Bounding the task.

In order to limit and focus the work, group members will try to define or redefine the boundary of the task. Such a definition requires the approval of other group members and changes in the boundary definition can lead to a reappraisal of outstanding sub-tasks.

Again, the shared understanding of the task boundary is a knowledge artefact that is proposed, negotiated and then accepted into the group's domain. If the perceived boundary of the task changes, then the next group state will be to focus back on understanding the task within the new domain. It might be that previously accepted knowledge artefacts need to be modified by the group. This is an example of the task-artefact cycle (Carroll et al., 1991) working at the micro level.

In the flora and fauna survey, one of the biggest problems each group had to overcome was deciding what was possible within the four-week survey period. In particular, they had to resolve two competing pressures of breadth versus depth in the survey. The following dialogue comes from one of these discussions:

> TIC – "… Common things we can deal with, but obviously there's going to be like a thousand types of plant".
>
> TIH – "I think we should aim at the big things, and not worry about the little details…"

Although this example shows a more negative attitude towards the task, it still also exhibits awareness of what is required to progress it. TIC has identified a specific problem with the granularity of data that they are trying to gather and, in voicing this issue, is encouraging his team-mates to re-evaluate their plans for data gathering. This was negotiated within the groups several times, but each time they would reach a point at which someone decided they had the correct balance and proposed this to the group. Once accepted, this naturally led the group members to reconsider what they now thought the task meant, what they understood and what was still missing. Each of the iterations of this process produces new group-adopted knowledge, which is used as artefacts in the task of trying to understand the complex super-task more fully.

Structuring sub-tasks.

As the group members begin to understand their task they start to structure the work as sub-tasks that are more manageable, either by requiring fewer people to complete them or by having a shorter timescale. An example of this is when one group tried to split the data collection into zones. From an initial suggestion by one group member, this developed into a three-way discussion:

> ADA – "How would it be if we worked on zones of different types of land? For example, this area here…" *(he points at a campus map they have on the table, and continues to expand on what he thinks the various zones might be)*

DUN – "This says to me why don't we build a system based on plants…"

ADA – "Yeah, so this one and this one are going to be quite similar…" *(He takes this idea on board and continues to build a profile of suitable zones – having the map in front of him gives him great control in this discussion and, although it is effectively a three-way conversation, everything flows though ADA and his use of the artefact)*

STA – "That makes a lot of sense for the presentation, however what maybe <DUN> is suggesting is that we have zones clearly defined … so that we know where we've been…"

ADA – "and it's quite easy to divide it up according to visible landmarks…"

When the group members are operating in this state, they need to manage their repository of artefacts so that they support the sub-tasks as available resources, i.e., they need to fit the appropriate knowledge to sub-tasks that it can support. The negotiation processes that the group undertake in this phase are aimed at defining meta-level knowledge artefacts that tie together existing artefacts, tangible or otherwise, into a package that supports a low-level goal. By this, it is meant that they will negotiate some combination of plan and resources that they think will enable someone to complete the sub-task.

The conversation in this example shows the difficulty that groups have in framing their existing knowledge in a way that is suitably structured for the way they decide to split tasks. In order that individuals or sub-groups can perform some sub-tasks, the group has to work very hard so that the correct group knowledge is explicitly tied to the correct sub-task, in a way the whole group agrees upon.

It was observed that the outcome or breakdown of this negotiation process could move the group to three other states. If the negotiation process led to agreement that the group had a fully supported sub-task then usually at some point there would be a phase of activity-focused interaction that led the group to move to the state where they negotiated the allocation of work instead. Occasionally, however, someone would identify that the group knowledge development had given the group sufficient resource to complete some sub-task and then the activity-focused interaction would shift the group's state to negotiating sign-off for completed sub-tasks.

At other times, the negotiation of sub-tasks led to the creation of knowledge artefacts that group members identified as important in developing existing sub-tasks and then the new knowledge would be used to shift the group into the state of developing existing sub-tasks.

When a group has co-located meetings as part of primarily distributed work, as in the flora and fauna study, this state is critical to the success of the meeting. Group members leave with a schedule of tasks and a personal mandate to use a subset of the group's artefacts to try to progress or complete those tasks before the next meeting.

Developing sub-tasks.

As the group members develop their understanding of the main task, they may need to redefine sub-tasks because their needs have changed, or they may see more complexity in a sub-task that shows it needs to be further sub-divided or modified.

In the flora and fauna study, this state was repeatedly observed as a precursor to re-bounding the main task. During the negotiation of how sub-tasks should be defined, a group member always noticed that the new knowledge artefacts created has challenged their existing understanding of the boundary of the task. In this study it was often observed that this was triggered by discussions of extra complexity that had been identified during data gathering between meetings.

In the following dialogue, the group is challenged by MAT to define more clearly what their output is going to be. This is an example of how clear activity-focus can be generated by group members challenging each other to improve on their ideas. MAT's original question is not itself clearly activity focused – he had no particular insight – but it forced the team to collaborate in defining their approach to the problem more clearly.

> MAT – "Have we any thought at all on how we're going to present this? … if we have any idea now, it might save us hassle further down the line"
>
> ADA – "The way I'd imagined was that we'd draw a map on it, with little lines coming off, but that might be incredibly busy, so we might have to get selective with the pictures" *The discussion continues between MAT and ADA, but then DUN says…*
>
> DUN – "I thought we were going to do areas, the areas that we identified as being similar…" *This is controlled by ADA, who shows that the two ideas are the same.*
>
> ADA – "But that would be an elaboration of the map idea, yeah?"

From the progression of this sub-task, the group are now able to re-evaluate what they have been doing individually, and how this now fits into the overall picture. If the sub-task itself is sufficiently complex – it may only be defined as an area of work the group knows it needs to address – then this state becomes a new iteration of the whole taskwork model, but at a lower level.

This example clearly shows the negotiation process for the adoption of knowledge into a group. ADA starts with a very clear idea of what he believes the group needs and proposes it, but the other group members go to great trouble to modify the idea, until what is finally adopted has been jointly constructed as part of a collaborative exercise.

Distributing work between group members.

Early in a group's development, members find it easier to identify sub-tasks that suit their own skills and competencies, and then volunteer to complete them. As group members gain a greater awareness of each other's skills and competencies they are more able to suggest work for other people or shared work.

Group collaboration requires the group members to take responsibility for parts of the shared work (Herrmann and Kienle, 2002). In the flora and fauna study, group members negotiated individual responsibility from the shared pool of identified sub-tasks. Combined with this was the return to individual responsibility for the artefacts previously associated with each sub-task. This cycle of knowledge responsibility is important when it comes to trying to complete sub-tasks. Group members take knowledge that the group has agreed to be usable for a sub-task, attempt the sub-task and then re-present the knowledge back to the group in a revised manner. The negotiation of acceptance of this revision is effectively the group deciding whether to 'sign-off' the sub-task as complete or not. If they are unable to do this, then the group will have to rebound the task again, as they clearly have not all understood the goal for the sub-task in the same way.

In describing the development of the sub-tasks, the thesis presented a three-way discussion between group members as they tried to identify and define zones on a map that would be a suitable sub-division of the survey. However, it was the fourth member of the group that waited for this discussion to resolve itself, before joining in with an attempt to divide the surveying of these zones among the group.

> MAT – "I was going to say, if we're doing it in that way, then it might make sense seeing how I've done woodland here"
>
> *(points to map)* "then I might as well do the woodland there, there and there…"
>
> *(more pointing)* "because then we don't duplicate stuff…"

This encourages ADA to explain areas he has looked at, and so what he thinks he is more suited to. This interaction leads to a period where a feeling of clear understanding of the task is less apparent. The group is working with the newly formed idea of zones, and so they are trying to feel for a best way to use it. They begin to rely on other group members more, rather than trying to force through their own fully formed ideas.

The group members will try to complete the sub-tasks allocated to them with the artefacts that the group has negotiated to be fit for that purpose. Once the individual owner of a sub-task has made this attempt, they will need to present this to the group, so that acceptance or rejection of the completion can be negotiated.

Completing sub-tasks.

For a sub-task to be completed, the work needs to be approved by the whole group in terms of a 'sign-off'. If a sub-task is not signed-off by the group, then group members will have difficulty in integrating that piece of work into the overall work towards completing their main task, forcing the group to re-evaluate what the main task boundary should be.

In the flora and fauna surveys, group members often proposed this 'sign-off' by sharing information that they had collected individually during the week. Because individual information capture is goal-oriented (Brown et al., 2000), the proposer has a particular purpose in collecting it and presenting it to the group. However, in the negotiation process group members might see a wider scope for the information, or see that it affects the overall understanding of the task boundary. Individuals presenting new knowledge to the group can quickly drive the group from low-level sub-task discussion to high-level main task discussion, because other group members see different things and make different links with the new knowledge artefact. This is another example of an artefact being modified at a low level by the task.

An example of this from the observed data came when a group member had taken some photos and got somebody else to identify the fauna in the photos for him. He tries to get the group to accept that this data is complete, but one other group member refuses to accept it. The discussion continues for about four minutes without being resolved, so in this case the appropriate 'sign-off' has not been made, finishing with:

> PET – "I think we've just hit the conflict that this survey was made to encounter, which was depth or breadth"
>
> TIH – "I'm not asking for depth. I'm asking for accuracy."

The discussion does lead to the group then discussing what is good and bad about this data, which then feeds back into their own sub-tasks and their understanding of the overall problem.

5.3 A Worked Example

This section illustrates in detail the concepts discussed in this chapter, by working through an example of one of the meetings recorded for the flora and fauna study. The meeting was the third (mid-point) meeting by the first group in the study, and was held by three of their four members (the minimum requirement to convene a meeting), identified as ADA, DUN and MAT. The meeting is broken into small sections for discussion, with the elapsed time shown at each break point. The original entries from the observer's SYMLOG Interaction Scoring Form for each of the sections is also included.

Also, during the analysis of these meetings, it became clear that the group work had phases where the required actions and interactions appeared to be quite obvious to the group's members. At other times this was more difficult for them to determine, and led to more discussion and team-related activity. This 'flow' in collaborative activity is investigated and reported in detail later in this thesis, so some early observations are discussed here.

The high-level 'flow' in this meeting essentially follows the pattern of beginning with good flow, followed by a patch with lots of disruptions and concluding with another period of good flow. The observations that indicate this are that initially the meeting starts with an element of routine; for example, at the very beginning ADA knows that they have to fill in the group record as a matter of procedure; after this, the group members know that having been working individually, they will need to appraise the others of the work that they have done. These clear objectives mean that the start of the meeting has a natural flow to it.

After this early controlled part of the meeting, there is less flow as it requires innovation from individuals to continually drive the meeting forward. However, once there has been some innovation, the collaboration between group members increases again and the meeting finishes strongly.

Elapsed Time: 0 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
0	ADA	GRP	ACT	DP	Asks what to do, as he is completing group record	PRO	DP	GRP

The meeting starts with ADA picking up the group record from the resource area and bringing it to the main table where the other two are sat. This means that the meeting starts implicitly in the *distribute between group members* phase. He then completes some notes about the convening of the meeting and the absence of the fourth member, STA, with the help of input from the other two.

ADA says that will do for the group record, moving the group into a phase where they *complete sub-tasks*. The three agree that the record is sufficient, and so the activity of completing the group record is effectively signed-off by the group's members.

Elapsed Time: 0.5 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
0.5	DUN	GRP	ACT	UP	Reports on his work	PRO	P	SIT
1.25	MAT	GRP	ACT	P	Agrees with DUN and reports	PRO	P	SIT

Having done this, DUN now offers to start the meeting proper by saying "OK, shall I start this one?" and getting responses of "Yeah" (ADA) and "Go for it" (MAT). He steers the group to a period where they try to *bound the task*. His issue is that there are far too many trees for him to record, and they are difficult to identify. This leads to a discussion about what is possible in the time available and what level of depth they can consider.

Elapsed Time: 2 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
2	ADA	GRP	ACT	P	Asks about getting a ref. book	PRO	P	SIT

Next, they shift again to trying to *understand the task* better. This shift is initiated by ADA, who asks "Can you get one of those little books?". He expands on this to explain that the 'little books' he is referring to are the sort of I-Spy recognition books that children use. DUN then moves on the conversation, by suggesting that they see if anyone has already done a survey of the campus.

Elapsed Time: 2.75 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
2.75	DUN	GRP	ACT	UP	Says – should see if study has already been done	CON	P	GRP
2.75	ADA	GRP	ACT	P	"Maybe we should look into …"	CON	P	GRP
2.75	DUN	ADA	ACT	UP	Still no answer from Estates	CON	UN	SOC
3	DUN	GRP	ACT	UP	Doesn't mind trying again	PRO	P	SIT
3.25	DUN	GRP	ACT	P	Feeling overwhelmed by task	CON	DN	SIT
3.5	ADA	DUN	ACT	UP	Can help with plants	PRO	P	SIT
3.75	MAT	DUN	ACT	UP	Can also help DUN	PRO	P	SIT

The next part of the meeting is quite messy. This does seem to be a characteristic of peer-led groups, where all of the group's members have ideas of what to do next, but there is no nominated leader. Also, this group has only met three times including this meeting, so they are demonstrating characteristics of norming in Tuckman's (1965) development phases – i.e., still finding ways of working together effectively.

It starts with ADA trying to move the discussion onto a *structure sub-tasks* phase, by saying "Maybe we should look into…", but DUN intercepts and draws the discussion into the same phase by cutting in with "I've still had no answer from estates". This stems from a previous meeting, when they had hoped to get some planting information from the university's estate management department. Because there's been no reply, they have to re-evaluate and move to *develop sub-tasks* by discussing whether they can salvage this activity.

This leads to a fast loop through the taskwork model's states. They decide that they are unlikely to get help from the estates management department, so they begin to *bound the* *task* again, based on this new information. DUN then says that he's feeling a bit overwhelmed by the task, so they move quickly to a discussion about what they now know about the task in a phase that helps them *understand the task*. From this they move straight onto *structure sub-tasks*, where they identify the tasks based on their new boundary and new understanding. When this moves to the *distribution between group members* MAT and ADA pick up on DUN's concerns and offer to take responsibility for the new activities.

Elapsed Time: 4 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
4	ADA	GRP	ACT	UP	Asks if anyone has a map	PRO	P	SIT
4	DUN	GRP	ACT	P	Says he's very busy programming	CON	B	SEL
4.25	DUN	GRP	ACT	P	Shows on map what he's done	PRO	P	SIT
4.5	MAT	DUN	ACT	UP	Confirms what DUN has done and adds own	PRO	P	SIT
5	DUN	MAT	ACT	DP	Asks MAT how he has classified plants	PRO	P	SIT
5	ADA	MAT	ACT	UP	Suggests a new area for MAT	PRO	P	SIT
5.25	DUN	ADA	ACT	P	Checks where this is	PRO	P	SIT
5.5	ADA	GRP	ACT	UP	Reports what he's done	PRO	P	SIT

Once they have situated and distributed this new work, they return to a lengthy discussion about what has been done so far and move to a phase where they each describe their work so that it can be assessed for sign-off. Nothing is considered complete (and the individuals presenting the work are not surprised by this), so again they look to review their overall project.

Elapsed Time: 5.75 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
5.75	ADA	GRP	ACT	P	Problem with counting animals	CON	P	SIT

ADA moves the group back into a phase where they *bound the task* by saying "But the issue seems to be with animals, is that 'cause they move around and they hide, they're actually quite hard to spot". His point for discussion is to identify how much effort they want to expend on trying to count these animals, and this impacts upon the definition of their overall task.

Elapsed Time: 6.25 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
6.25	MAT	ADA	ACT	UP	Uni. Not host to much exotic stuff	PRO	P	SIT
6.5	ADA	MAT	ACT	P	Some things are hard to spot	CON	DP	SIT
6.75	DUN	ADA	ACT	P	ADA has opposite problem to DUN/MAT	PRO	P	ADA
7	ADA	GRP	ACT	U	Agrees	CON	P	SIT
7.5	ADA	GRP	ACT	P	Asks where North is (on map)	PRO	P	SIT
7.75	ADA	GRP	ACT	UP	Works out with compass and points	PRO	P	SIT

MAT moves the discussion back to trying to *understand the task* by initiating a discussion on what the likely fauna are going to be, noting that there's "nothing exotic" on the campus. This discussion continues with them weighing up the relative problems with flora and fauna. They decide that generally speaking there's not enough fauna to observe, but there's far too much flora for them to process.

What they're trying to understand shifts from topic to topic, but all the time they're building shared group knowledge.

Elapsed Time: 8.25 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
8.25	ADA	GRP	ACT	UP	Declares a group plan	PRO	UP	SIT
8.25	DUN	MAT	ACT	DP	Asks how he got his data expertise	PRO	DP	MAT
8.5	MAT	DUN	ACT	P	Tells him how	PRO	P	GRP
9	DUN	MAT	ACT	UP	Explains problem of non-native trees	CON	N	SIT
9.25	MAT	DUN	ACT	P	Asks if there are tags on the trees	PRO	P	SIT

At this stage, the first effort to wrap the meeting up is made by ADA, who says "OK, then the plan is to carry on as we are". As such, he brings the group into a phase where they look to *structure sub-tasks*; the others agree, so this is relatively straightforward to achieve, but then DUN asks MAT how he identifies flora. MAT's subsequent explanation helps them *develop sub-tasks*, by sharing their ideas on the best approach for identification.

Elapsed Time: 9.75 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
9.75	MAT	GRP	ACT	UP	Asks for thoughts on presentation	PRO	UP	SIT
10	ADA	MAT	ACT	UP	Makes suggestions	PRO	UP	SIT
10.5	MAT	ADA	ACT	P	Agrees	PRO	P	SIT
10.5	DUN	GRP	ACT	UP	Questions their ideas	PRO	UP	SIT

MAT now shifts the conversation to the output – i.e. the poster that they need to present, saying "Have we had any thoughts at all on how we're going to present this?". By this, he has moved the group into another phase where they attempt to *bound the task*. The reason that this should be thought of as a bounding activity is that they already understand that they need to produce the poster – what they're doing is using their knowledge of the current state of the activities to try to give a boundary to the scope of the poster.

In this phase they negotiate exactly what is required. There is a discussion as to whether they restrict their output to certain flora and fauna, or certain locations, or both.

Elapsed Time: 10.75 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
10.75	ADA	DUN	ACT	U	Suggests that the ideas are the same	CON	U	DUN
10.75	DUN	ADA	ACT	UP	Explains his idea further	PRO	P	SIT

When they are clearer about this new boundary, they move again to working on *understanding the task* – that is, they look to fill in some of the detail. This is initiated by ADA, who says "Yeah, but that would be an elaboration of the map idea"; DUN replies "Exactly", and then they are away and working on the detail of the presentation.

Elapsed Time: 11.25 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
11.25	ADA	GRP	ACT	UP	Volunteers to draw	PRO	P	SEL
11.5	MAT	GRP	ACT	DP	Says he can't draw	CON	P	SEL
11.5	DUN	GRP	ACT	UP	Says they need to decide on resources	PRO	UP	SIT

This is a key phase in demonstrating how the model represents the breaking down and completion of complex tasks. In the previous few minutes of the meeting the group members have developed their understanding of another part of the task – in this case the poster – and now they can associate well-structured activities to be associated with it. This cycle of picking away at the complexity is critical to tackling the uncertainty of complex tasks.

The group now continue to *structure sub-tasks*, in particular the sub-tasks relating to the creation of the poster. DUN says that they'll need to decide on the resources required, as they'll need to check that they have them in advance. The other group members make suggestions, such as pens, scissors, glue, etc.

Elapsed Time: 12.5 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
12.5	MAT	GRP	ACT	P	Need to check with STA	PRO	DP	GRP
12.5	ADA	GRP	ACT	UP	Summarises what's required during week	PRO	UP	GRP
12.75	MAT	GRP	ACT	DP	Asks about an area	PRO	P	SIT
13	ADA	MAT	ACT	UP	Suggests a border for the area	PRO	P	SIT

The group now make an effort to wrap up the meeting. They move to another phase where they try to *complete sub-tasks*. This time, they each discuss what they have outstanding and, as such, get validation from the other group members that their previously-allocated sub-tasks are not yet complete.

Elapsed Time: 13.5 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
13.5	DUN	GRP	ACT	UP	Asks GRP to agree on drawing tool req.	PRO	UP	SIT
14.25	DUN	GRP	ACT	UP	Says why five colours are needed	PRO	UP	SIT
14.75	ADA	GRP	ACT	P	Asks: anything else	PRO	P	SIT
14.75	MAT	ADA	ACT	UP	Scissors and glue	PRO	UP	SIT

As they discuss their outstanding work, the group members realise that they still have not established the requirements for the poster in the detail that they would like, and so they move to another phase where they try to *bound the task* by detailing the output that they intend to produce to complete it. In this discussion there are a number of quick loops between *bound the task* and *understand the task*, as they shift between the nature of the output and the detail of their understanding about it.

Elapsed Time: 15 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
15	DUN	GRP	ACT	P	Asks if they can print lists	PRO	P	SIT
15.25	ADA	DUN	ACT	UP	Decides that they can	PRO	UP	SIT
15.75	MAT	GRP	ACT	P	Says he already has made lists	PRO	P	SIT

At this point, ADA tries to conclude the meeting by saying "OK, anything else to add?". DUN replies by asking if they need paper or if they can print their lists of identified flora and fauna. They move briefly to another phase where they try to *understand the task*, as they discuss what contributions their lists will make to the final output. They then move quickly to *structure sub-tasks*, where they negotiate exactly what to list and then through to *distribute between group members*, as they identify who will do what work.

Elapsed Time: 16 minutes

Time	Who Acts	Toward Whom	Act / Non	Direc-tion	Ordinary Description of Behaviour or Image	Pro / Con	Direc-tion	Image Level
16	ADA	GRP	ACT	UP	Summarises notes he's written	PRO	P	GRP

ADA tries once again to conclude the meeting, this time by beginning to complete the group record. The others help and they finish the meeting by a short phase to *complete sub-tasks*, where they discuss what needs to be in the record and then all the group members agree that it is complete.

5.4 Conclusions

The study shows that co-located work groups address complex tasks by organizing them into manageable sub-tasks that are both informed and supported through the adoption of both tangible and knowledge-based artefacts. Although this is a recurring process throughout group meetings, group members are largely unaware of it because it happens at a low level and states shift quickly during activity-focused periods of the meetings.

A taskwork model has been developed that can be used to help explain the behaviours and activities that take place at a low level in group work. It can be used to help model groups more effectively, and show how existing approaches should be modified to better support co-located work groups. The relationship between this process model and group knowledge adoption provides a useful insight into the way in which new groupware for co-located groups could be developed.

Historically, Groupware Support Systems (GSS) have been categorized as Group Decision Support Systems (GDSS) or Group Communication Support Systems (GCSS) (Kraemer and Pinsonneault, 1990). The thesis has shown that in co-located problem-solving work groups the two categories are interdependent, as an awareness of communication is required to fully understand and support decision-making.

Groupware systems that support the development and organization of group knowledge should also support a meta-level awareness, so that the link between group knowledge adoption and task sub-division is apparent to the group members as they work. This would help group members keep in focus their reasons for knowledge adoption.

In many GSS, particularly GDSS, there is a focus on explicit voting on knowledge adoption following a period of negotiation (Stahl, 2006). Although this is possible to support for big decisions, it is impractical at the level reported in this study. The knowledge artefacts are too small and the group's focus changes too quickly; in this case explicit voting would likely be a cause of production blocking.

A promising area of research to find support for these low-level interactions is in knowledge management (KM). Many KM systems use methods to externalize knowledge so that it can be structured in useful ways. However, although many systems exist to capture and structure knowledge, few use this knowledge to tailor the KM system to the group. Mandviwalla and Olfman (1994) found that one of the key requirements of groupware was that it should be adjustable to the group's context and, while this has been addressed at a high level, the model presented in this paper shows how lower level group interactions can be structured as useful knowledge artefacts. Malone et al. (1992, 2001) introduced the idea of *radical tailorability*, where users can easily see and modify the reasoning processes of their support systems, as well as the data captured within them. This is the approach needed to develop the next generation of groupware that deal with interactions at a much lower level than those in existence today.

Additionally, the research area of computer-supported collaborative learning (CSCL) has provided insights into many of the issues facing task-oriented work groups (Stahl, 2006), but the generalisability of these findings is often undersold. Learning is just as important outside the domain of formal education and all group development is tightly coupled with learning within the group.

5.5 Reflections on the Study

This section reflects both on the design of the study and its outputs, to consider what could be improved in future work and any interesting points that require further investigation.

One part of the study that did not work as intended was the use of individual diaries. The study design had deliberately left the use of this resource open; the intention of this was to give the participants an open brief as to what they recorded. The problem was that as the task developed, not all participants saw an obvious use for their diary. Those that did find a use for the diary did so inconsistently and overall the data from this source was weak.

On reflection, a better method for incorporating diaries into a study like this, would have been to direct a particular use for them at the outset. In this case, it may have been more fruitful to instruct the participants to write a brief record of each time they performed task-related work away from the co-located meetings.

The analysis of this study focussed upon taskwork and how complex tasks can be broken down into achievable activities. Another factor not directly considered in this study is teamwork, i.e., the extra work needed for group members to collaborate over the task. However, teamwork clearly influences a number of phases of the taskwork model.

The taskwork model does not explicitly model the complexities introduced by sub-groups. There was some sub-group development during both groups' projects, both in the co-located settings and between meetings. However, sub-groups break out to attempt activities that have already been sanctioned by the group, and so, when the sub-group rejoins they effectively report as a single actor: any information they provide is negotiated in from sub-group to group, rather than individual to group and activity sign-off scales in the same way.

During the analysis of this study, it became clear that the activity-focussed interactions that were observed defined something that could be described as a 'flow' in the collaboration. Sometimes when the groups were working, they seemed to be making good progress with the task; at other times they got stuck, or were slowed by particular disruptions, such as not having the same, shared knowledge. The taskwork model demonstrates how they use the good collaborative flow to break down the complexity in the task that they attempt, but it does not give a good understanding of the flow itself. In the following chapter (Chapter 6), what it means to have collaborative flow and where disruptions in that flow might arise is discussed. Then, in Chapter 7, a much simpler series of tasks is investigated, to analyse the different effects of both taskwork and teamwork on collaborative flow.

6 The Flow of Collaboration

> Flow with whatever is happening and let your mind be free. Stay centred by accepting whatever you are doing. This is the ultimate.
>
> Chuang Tzu, Chinese philosopher, 4th century BC

This chapter introduces the idea of *flow in collaboration*. A group has good collaborative flow when all its members have an implicit shared understanding about the activities that they need to undertake, and they are capable of doing so. When outsiders observe groups, in any domain, and they all seem to be in synch, all doing things that appear to be part of a shared task, then they appear to have a very natural way of working together, and this natural way of working gives an appearance that together they *flow*.

The chapter goes on to introduce an interesting problem that occurs in all types of interaction between people – a *disruption in flow*. The thesis considers collaborative flow to be a desirable ideal for the state in which a group can collaborate, and so the disruptions represent the problems that prevent a group from working to their maximum efficiency. Flores et al. (1988), in reporting the development of systems that supported coordination, noted that the 'designers job is to identify recurring breakdowns, or interruptions in ongoing activities, and prepare interventions to resettle the activities in ways that cope with or avoid those breakdowns'. In this thesis, the same importance is attached to disruptions in collaborative flow, and for GSS designers to understand and react to these disruptions.

In order to understand what good collaborative flow is, and when and why it is being disrupted, the thesis develops an understanding of the nature of efficiency and effectiveness of collaboration in small groups and to reason how this can usefully be observed.

The idea of *flow* in creativity was introduced and developed by Csikszentmihalyi (1996). He concentrated on the creative flow in individuals, but this was later extended into the creative flow of groups by Sawyer (2003). The ideas of creative flow in both individuals and groups are reviewed here to situate their relevance to flow in collaboration.

6.1 Flow

Csikszentmihalyi (1996) sees *flow* as a mode of being where the individual is capable of being extremely efficient in whatever they happen to be doing. For him, flow is the individual's experience of this efficiency and, in particular, he focuses upon the idea that whenever an individual is experiencing flow in what they're doing, then they derive a particular enjoyment from this. In Csikszentmihalyi's research, he notes that the terms people use to describe this experience are the same regardless of the domain: athletes, artists, scientists, etc. all experience phases in their activities when everything is working well and it is particularly pleasant to be engaged in that specific task at that specific moment in that specific environment. From this, he identified nine elements that were repeatedly mentioned by people that he interviewed, each of which signalled that an experience was enjoyable. Here, each of these is reviewed in turn, and the thesis reflects upon how they relate to the studies discussed so far:

There are clear goals every step of the way. By this, Csikszentmihalyi means that when a job is enjoyable, there are clear goals that the individual can perceive and achieve, and they are aware of the activities required to achieve those goals and how to perform those activities. It is important to qualify the second part of this criterion – 'every step of the way' – as one could reasonably ask: every step of the way to what?

In the tasks that have been presented thus far in this thesis, the participants have been attempting a task for the first time; in the case of the jigsaw study, this was a relatively simple task and some participants could draw on experience from very similar tasks that they had attempted previously (e.g. other jigsaws or similar spatial puzzles), and in the case of the flora and fauna study the participants generally had little direct task experience to draw upon. In both cases however, there were no clear plans at the start for every step, or every activity, required to complete the task.

As the thesis showed with the taskwork model in Chapter 5, when groups attempt complex or unstructured tasks they develop partial understanding of their task, which yields some activities that they can undertake, the outcome of which helps develop their understanding of the task – and so the iterations continue, until the task is complete or the group members stop for some other reason. Therefore, when groups are attempting these complex tasks, they have certain periods where they have clear objectives and others where the task needs further understanding; the periods when the group members have clear objectives could be periods of group work where there is flow.

There is immediate feedback to one's actions. When someone is experiencing flow in their work, it is possible for them to tell how well they are doing. Csikszentmihalyi gives examples such as a musician hearing immediately that they have played the right note, or a rock climber knowing that they have found the right hold – an implicit awareness taken simply from not having fallen.

When performing activities with or on behalf of a group, there are two levels of feedback. First, there is environmental feedback to the individual as a result of whatever they do; second, there is the feedback from other group members, by their reaction to whatever the individual has done.

In the jigsaw study, the relatively simple task was scheduled over a single session with the group members all co-located; therefore, at a broad level, there was immediate feedback between group members. This is qualified to be only at a broad level, because group members are far more likely to notice when others are not attempting the activity they expected, rather than notice individual mistakes. For example, one group member might question whether another should be working on the border, but would be less likely to notice if a single piece had been mislaid, unless it impacted directly on their own work.

In the flora and fauna study, there was not always the opportunity for immediate group feedback, as the group members attempted activities outside the co-located meetings. Group members would have to rely on their own judgement against the group's definition of the activity as their immediate feedback. The feedback from other group members only came when an individual's output was presented at the next co-located meeting. This illustrates a key difference in the capability of a group to flow in distributed, asynchronous work, compared to the possibilities in a co-located setting.

There is a balance between challenges and skills. When an individual is flowing, they feel that their abilities are a good match for the activities that they undertake. Csikszentmihalyi believes that if this balance is not maintained, then the enjoyment of the activity is lost. If the activity is too easy, then it leads to boredom. Conversely, if the activity is too difficult (or is perceived to be too difficult), then it leads to frustration. Bandura (1977), in his work on self-efficacy (see Chapter 3), also observed that if someone believes that their efficacy is too low for a particular activity then they are likely to decide not to attempt the activity if they have the choice.

In the group context, group members not only have to match their skills and abilities to the requirements of the activities that they have identified, but also they have to be aware of each other's skills and abilities so that they can distribute work effectively between themselves. When looking at a relatively simple task, such as the jigsaw puzzle, everyone was able to sort and lay pieces of jigsaw, but what was observed was some empirical evidence of frustration if more than one group member wanted the same responsibility – a clear example being the struggle for leadership within one of the groups.

In the flora and fauna study, the greater complexity of the task meant that the group members had to be quite explicit about what they thought that they were and were not able to do. The groups' negotiations about what skills were necessary, who had which skills and to what degree not only determined who did what activities, but also shaped the task itself. It seems likely that this would be a general trend, where in an uncertain environment group members will bend the activities to fit with things that they think they can do.

Action and awareness are merged. When an individual is in flow, they are focussed completely on what they are doing. Csikszentmihalyi (1996, p112) draws this criterion together with those before it, saying 'one-pointedness of mind is required by the close match between challenges and skills, and it is made possible by the clarity of goals and the constant availability of feedback'.

In both the jigsaw and the flora and fauna studies there was evidence of individuals fully engaged in a solo task, despite being co-located with other group members. For example, in the jigsaw study, both groups managed the task by giving an area of the puzzle or particular activities to different members – when they were completing these activities, they gave the appearance at times of being in flow. Similarly, in the flora and fauna study, when the groups reached the point of having to make their poster, they distributed activities that were completed in the co-located setting, but individuals gave the impression of being fully focused on an individual activity.

However, there are many times in co-located group work where full focus on an individual activity is either not possible, or perhaps just not desirable. In group settings, the ability of an individual to separate awareness from the task they are performing, while still being able to do the task in hand is considered important; for example, Heath et al. (2002) noted that ‘collaborative activity in complex organisational environments rests on the participants’ abilities to remain sensitive to each other’s conduct whilst engaged in distinct activities’. They are referring to large-scale complexity, e.g. a big company or some such like, but this is also true in small groups working on complex problems. Even in the relatively simple task of the jigsaw puzzle, the single shared and linked output of the constructed jigsaw required group members to maintain an awareness of what each other was doing, even when they had distributed activities that could be completed individually.

Distractions are excluded from consciousness. The ‘distractions’ that Csikszentmihalyi is referring to with this criterion are internally-held distractions, such as worrying about things not related to the individual’s current goal, rather than external distractions, such as someone else coming into a room where they are working.

It is difficult to assess this post-hoc from the studies reported so far. However in the jigsaw study it may be that the time pressure – the groups were encouraged to complete their puzzle in a very tight timescale – helped group members to focus, especially as they were aware that they only had to do so over a relatively short period of time.

Over a longer period of group work, such as that observed in the flora and fauna study, it does not seem reasonable that group members will be able to work consistently without distraction. This means that over time the periods when a group might be said to be ‘in flow’ will be sporadic. This supposition is consistent with the observations from the flora and fauna study, where particular periods of activity focus that drove the progress through a complex task were seen.

There is no worry of failure. When an individual is in flow, their involvement in the task is too great for them to be concerned about failure. Csikszentmihalyi says that some people describe this as a feeling of control, but cautions that in flow this is not necessarily control, rather it is a general absence of the individual concerning themselves as to whether they are in control or not. His argument here is that if someone was consciously assessing whether they were in control, then they would not be totally focused on the task and therefore could not be in flow.

There are two difficulties in looking for this criterion in the studies reported here. First, as with the previous criterion, at an individual level this is an internalisation, and to draw that out at any given moment is problematic; of course, the individuals can be asked afterwards, but this is prone to error. Second, the studies are both laboratory based and, as such, consideration must be given to what the participants' motivations may be in undertaking the study, to try and understand whether they would ever have grounds to worry about failure. There are two good reasons, even in these artificial settings, that the participants would have grounds to worry about failure, if they weren't in flow: first, in both studies group members knew that other groups were doing the same study and that their performance would be compared; and, second, none of the groups were ever comprised of people that had worked together before, so people could not be sure within the groups how they would appear to their peers. If anything, the participation in the studies reported in this thesis was surprisingly committed, suggesting that flow does occur even in artificial settings.

Self-consciousness disappears. This links to the previous criterion, as again it represents a lack of awareness outside the task when the individual concerned is in flow. Csikszentmihalyi suggests that self-awareness is typically burdensome and that when the individual is in flow this burden is lifted. He goes on to say that 'after an episode of flow is over, we generally emerge from it with a stronger self-concept; we know that we have succeeded in meeting a difficult challenge' (Csikszentmihalyi, 1996, p112).

These observations again fit very closely with Bandura's (1977) concept of self-efficacy. When an individual has been in flow with respect to some particular task, they emerge with a general sense of achievement. In the jigsaw study, it was observed that this sense of achievement, or a sense of lack of achievement, had an impact upon the individual's self-efficacy (in the four categories measured in that study).

In the flora and fauna study, because the overall co-located meeting times were much longer than those of the jigsaw study, it was easier to see the effect having to hold meetings in a slightly artificial setting. One of the noticeable effects was that group members, some more than others, were conscious of the recording equipment and therefore self-conscious about what they said or did; however, it also demonstrated how self-consciousness dissipates when group members are engaged. Comments about the equipment, who may be watching, etc., were always made either at the start or at the end of the meeting, when participants' levels of engagement in the group activity were low.

The sense of time becomes distorted. Csikszentmihalyi suggests that when in flow, an individual's sense of time can be warped to feel shorter or longer depending upon the circumstances. If someone is fully absorbed in a task, then several hours may pass but that person will feel that the time has gone very quickly, perhaps feeling like it was just a few short minutes. On the other hand, if someone is particularly adept at a task, or some of the activities within it, then relative to less skilled people they may have a sense of time being slowed – for example, a racing driver will have a greater feeling of time when asked to drive a car quickly than an inexperienced driver would have.

Other studies have also looked at situations where different individuals' perception of time around the same, shared task is influenced in different ways according to their particular involvement in that task at any given time. Benford and Giannachi (2008) looked at the individual's relative sense of time (i.e., relative to the other people involved) when engaged in a distributed game. They looked at the differences of experience between story time and clock time. There is an interesting parallel between that study and the experiences of group members in the flora and fauna study. The study itself took each group roughly one month, but the vast majority of the progress was made in the weekly co-located meetings; therefore, the project time moved at very uneven paces relative to the clock time. Also, as group members performed asynchronous activities away from the co-located group meetings, they also would have had different experiences of project time as compared to the overall time elapsed.

It was also possible to see in both the jigsaw and the co-located aspect of the flora and fauna studies that the participants experienced this sense of time distortion. In the jigsaw study, both groups of participants expressed surprise when their allocated 15 minutes to complete the puzzle ran out. In the flora and fauna study, examples of group members being in flow could be identified by their comments about lack of time.

The activity becomes autotelic. 'Autotelic' is a Greek-based term for something that is an end in itself; the opposite term is 'exotelic', which describes things that people do simply because they have to, as work towards a different goal. This criterion differs from the others slightly, in that it would not be unreasonable to believe that the other eight criteria for flow could happen regardless of previous experience if the task is sufficiently engaging for someone; but in the case of an activity becoming autotelic, this suggests that a certain amount of repetition is necessary for the transformation to take place. This might come from repeating the same task, or it could come from using prior experience of something that is transferable – in this case, the individual would need to see how to bridge the gap between the ability required for one activity and recycling the experience from that into another activity later.

When it comes to group work, much of our evidence for autotelic activities observed so far can be drawn from the flora and fauna study, where the group members had sufficient time to repeat activities enough times to be comfortable with them. The strongest candidate for autotelic activity in the study of the two groups is the teamwork itself. Our observations of the groups as they developed followed the stages of Tuckman (1965), and this development in itself is one that leads group members from exotelic activity to autotelic activity. Amongst the taskwork activities, there was little evidence of the repetition necessary for this development.

Each of Csikszentmihalyi's criterion for flow describes a way in which an individual approaches or is influenced by a task in a way that enhances their interaction with that task. As they have been reviewed here, the thesis has given some evidence of how these criteria manifested themselves in the presented studies.

The next step is to ask what is *group flow*? Chapter 3 discussed the problem of developing group properties from individual characteristics and illustrated this with Bandura's (1977) theories of self- and collective efficacy. With group flow there is the same problem – is it some factor of the flow experienced by individuals, or is it an independent group-emergent property?

Sawyer (2003) extended Csikszentmihalyi's (1996) ideas of flow to encapsulate group flow as 'groups that are collectively in a flow state' (p43). However, he still sees group flow as a group emergent property that is independent of whether the individuals are in flow. Generally speaking, it is likely that when a group is in flow then the individuals that comprise that group are also in flow, but not necessarily: it is possible that a group is working together very efficiently, even if the individual group members are not enjoying the experience very much.

Sawyer's work is grounded in creativity. The following section looks at how group flow is particularly relevant in collaborative group work. Collaborative flow is defined and an argument is made for how to look for this phenomenon in a study (presented in the next chapter).

6.2 Collaborative Flow in Groups

Drawing from these ideas of flow in creativity, *collaborative flow* is the term used in this thesis to describe how well a group is working together on a shared task, where the group's members also have a shared goal. If they have good collaborative flow, then they are working well together; if they have poor collaborative flow, then they are not doing so. In the remainder of this chapter, there follows a discussion of what it means for a group to have good collaborative flow and the possible causes for this not happening. As with Sawyer (2003), the thesis argues for the idea of flow in groups as a group-emergent property that may occur irrespective of whether individuals are in flow.

Collaborative flow is more specific than Sawyer's (2003) notion of group flow. The difference between flow in collaboration and the more general group flow is that when the group flows in collaboration it is making direct progress towards completing its shared task. As was observed in the flora and fauna study, there are specific periods of activity focus that propel problem-solving groups forward towards achieving their goal; this can only happen when there is collaborative flow.

Collaborative flow is affected by the need for teamwork in co-located problem solving groups. As the thesis has shown in earlier chapters, groups need to perform teamwork – i.e. those activities required to enable more than one person to work together on the same task – in order to collaborate. At some level, this could be seen purely as the cost of collaboration, i.e. if a group could all work on a shared task without any interaction and this work was completely effective and integrated, then the group's members would be able to spend all their time on the task. However, what has been observed in group work, is that the interaction generates many group-emergent properties, including new shared knowledge artefacts that are stronger and more pertinent to the task than any individual contribution could be. Therefore, it is important to be aware that although there is always some up-front cost to teamwork activities, the longer-term payback may be in better collaborative flow than would have been possible otherwise.

What collaborative flow does not represent is the outcome of the task, instead it is a way of determining whether the process of working together is what the group, or its sponsors, would like to develop when the group is formed. An example of this is in football: a player makes a run down one wing and crosses the ball into the box. In one scenario, another player anticipates this run, reaches the cross and heads the ball just wide of the goal – here the outcome is not what was desired, but there was a good collaborative flow. In a second scenario, nobody anticipates the cross, but the ball bounces off the back of a defender's head into the net – here the outcome, i.e. a goal, is exactly what was required, but there has not been good collaborative flow.

So, is good collaborative flow an expression of high group efficiency, high group effectiveness, or both? Each of efficiency and effectiveness, with respect to group collaboration are considered below, followed by a discussion of possible links between the two.

6.2.1 Efficient Group Collaboration

This thesis defines *efficient group collaboration* as all group members doing what is required by the group to complete the task in the most expedient way at any given time.

In complex or unstructured problem-solving tasks, determining whether someone, or the group as a whole, is performing an activity that will ultimately be relevant to the task is difficult. It may be that on reviewing a project after it is complete, a group would not do many of the activities that they undertook along the way, or perhaps they would do them differently, or in a different order. However, that does not necessarily mean that a group, or its members, was not being efficient at the time. This is investigated further in Chapter 7, when a study of groups repeatedly attempting the same task is introduced into the thesis.

It is necessary to make the distinction between achievable efficiency and optimal efficiency. An achievable efficiency for a person is if someone is making the maximum use of their knowledge and capabilities, even if they are less optimal than they could be with practice, or even if they are less than somebody else's capabilities. An achievable efficiency within a group is slightly more complex, as it is also affected by the differing capabilities of its members, i.e. the most capable person for an activity within a group must be the one attempting it for the group to be efficient (although it is important to note that capability to attempt an activity includes availability, so if the most able person for an activity is not available, then they do not have the capability to attempt it). By comparison, an optimal efficiency is a theoretical 'best attempt' at a task, in which the best-known people were attempting the task in the best-known way. With even the slightest complexity or novelty in a task, the optimal efficiency will not be understood until after the task has been completed, and perhaps not even then.

So if a collaborating group is achieving a level of efficiency commensurate with the current knowledge and capabilities of its members, then does this represent collaborative flow? The answer to this seems to be no, this does not fit with the general idea of flow, where people, and at some level the whole group, are somehow 'in the zone', i.e. doing what they do in some sort of naturalistic way. A group's achievable efficiency may fall well short of this if they are not familiar with the task, the other group members, or both.

6.2.2 Effective Group Collaboration

If the collaborative effort of a group has been effective, then to an outside observer the outcome of the task would be judged to be a success. Therefore, a measure of the effectiveness of group collaboration has to be a measure of the quality of the group's output. González et al. (2003) describe 'group effectiveness' as the aggregation to group level of the effect of the group's members' behavioural performances or actions; when these behavioural performances or actions all relate to a specific collaborative task, then this is a good definition for *effective group collaboration*.

As with efficiency, there has to be some distinction made between an achievable level of effectiveness within the group and an optimal level of effectiveness with respect to the task. A group would meet an achievable level of effectiveness if it were possible to answer in the affirmative *has this group achieved the best solution it was capable of for this task?* Whereas, the group would have reached the optimal level of effectiveness if it were possible to answer in the affirmative *is this the best possible solution for this task?* Sundstrom et al. (1990) make the link between group development and effectiveness, suggesting that the group's capability to be effective increases as it builds through the phases of development; also supported is the argument that this capability for effectiveness increases because during a group's development they need to allocate less time to teamwork activities and can therefore spend more on taskwork activities.

Another way of looking at group effectiveness is to apply Simon's (1957) rule of *satisficing*. In this case, instead of looking for the best possible solution for a task, either with or without respect to the group's members' capabilities, a satisficing solution would answer *is this a good enough solution for the task set?* To answer this, the assessor would have to understand the requirements of any sponsors of the task, rather than those of the group members contributing to the solution.

With respect to collaborative flow, the overall effectiveness of the group in producing a solution for their task is not relevant. As was explained with the football analogy, the final outcome does not really indicate whether the group was working well together, as this may ultimately be measured against factors over which the group members have no control, or factors which they were unaware of when they undertook the task. However, at a lower level, effectiveness may be a relevant pointer to collaborative flow. As the thesis discussed earlier, over time collaborative flow may come and go within the group and the periods of collaborative flow may represent a period of effectiveness relative to the group's state at that point, regardless of the overall outcome of the task.

6.2.3 Efficiency vs. Effectiveness

Given the distinction that the thesis makes between efficient group collaboration and effective group collaboration, it can be reasoned that there may or may not be a link between the two. There are three possibilities: one is that there is no link between efficiency and effectiveness, and the two measures are completely independent; alternatively, it may be true that the more efficient a group is, then they are also more effective; there is also a third consideration, that a certain amount of teamwork is always necessary for a group to be effective (which would mean that certain short-term inefficiencies in taskwork lead to an observable and predicable long-term benefit to the group and overall task completion). These alternatives are considered in the analysis of the study presented in Chapter 7.

6.3 Disruptions in Flow

Now the thesis shifts focus to the problem associated with maintaining flow in collaboration – that of the disruptions to it. All non-trivial collaborations experience disruptions in flow. Typically, as groups of people work together on a shared task, through teamwork activities they build the common ground and group-shared knowledge that enables effective collaboration. However, although this is the general aim and usually the overall trend of a successful group, there are periods when shared understanding is lost and a repair activity takes place before the group can progress their task further. The thesis terms these incidents 'disruptions in flow', and they may be as trivial as someone losing concentration and missing an important utterance, or larger disruptions such as someone being absent from a meeting.

If it is accepted that it is not possible to entirely prevent these disruptions from occurring, then a new and interesting area of research will be to find ways of supporting groups through disruptions, so that the damage to their effectiveness is minimised. One means of providing this support is to better understand how knowledge is shared in groups so that when someone lacks knowledge because of a disruption, non-intrusive support systems could help them catch up.

A disruption in flow can be defined as *a point at which two or more members of the same group no longer have a shared understanding on either ongoing taskwork, or ongoing teamwork, or both*.

As a disruption in flow represents a loss of shared understanding that leads to a group being less capable of achieving collaborative flow, the thesis must consider the common types of process construct that are used to describe sub-optimality in groups and consider whether these represent or influence disruptions in flow.

6.3.1 Production blocking

Production blocking is a commonly accepted phenomenon that occurs in groups when one person's work prevents someone else from making the contribution that they have in mind. In the literature the term has been particularly related to *brainstorming*; the reason for this is that brainstorming, when used to refer to the formal method, rather than the loose 'group trying to think of a solution to a problem' that often appears, is structured to be turn based – this means that if you have an idea when it's not your turn, you will be blocked from articulating it to the group.

This is a likely factor in some disruptions in flow. Specifically for co-located problem solving groups, this effect is a possible explanation for short-term misunderstandings that occur when the group members are trying to understand or bound their task more clearly. If one person is 'holding the floor' – i.e., drawing the attention of others with either speech or gestures – while other members of the group also want to share ideas, then a disruption of flow will occur that must be resolved.

6.3.2 Free riding

Free riding is another widely cited term that represents a common group dynamic; it is used to describe a deliberate failure to contribute fully to a task. Forsyth (1999) defines free riding as 'contributing less to a collective task when one believes that other group members will compensate for this lack of effect', and this definition is representative of the manner in which the term is applied in the academic literature.

Although free riding is, at some level, associated with disruptions in flow, it is not the type of dynamic that the thesis is trying to describe when proposing the term. A potential disruption in flow from free riding would be that the person who is wilfully not contributing as much as they could already knows things that others have to work to discover. A disruption persists between the various understandings of the group members, and therefore limits their capability for collaborative flow, until the group members have shared understanding again. This could happen by the person that is withholding the information deciding later to share it, or by other group members independently discovering the same information.

The reason that this falls outside the definition of disruptions in flow, is that the range of phenomena that the thesis is trying to capture, describe and support with the term are those that all parties would like to repair or avoid; the problems of people deliberately not contributing to collaborative activities are outside of its scope.

6.3.3 Sucker effect

The *sucker effect* is related to free riding. This is generally taken to stem from the belief by a member of a group that one or other members of their group are free riding. The term itself means that the group member holding this belief, and not wishing to be taken for a 'sucker' – i.e., doing the others' work for them – wilfully contributes less to the group work than they could and begins free riding. This can create a cycle, as others then might perceive this free riding and withdraw from giving their own best effort.

For the same reason that the thesis has discounted free riding from the idea of disruptions in flow, it also discounts the sucker effect as it is wilfully destructive and therefore needs to be supported by different means than the effects of accidental misunderstandings.

6.3.4 Evaluation apprehension

Cottrell (1972) proposed the idea that people learn to associate co-location with evaluation, and because of this they are apprehensive when other people are around. In the domain of co-located problem solving groups, *evaluation apprehension* can enhance performance on simple tasks, but impede it on more complex ones (Forsyth, 1999). A possible reason for this is that the apprehension enhances the *doing* of activities but inhibits *reasoning* about them.

This effect might help to explain how some disruptions in flow occur. As has been discussed previously, the negotiation process for individual knowledge artefacts to be adopted by the group lays the individual open to evaluation by the group and so this may lead to a reluctance to propose ideas, particularly in the early phases of group development, for example, forming, storming or norming in Tuckman's (1965) terms.

6.3.5 Coordination losses

The problem of *coordination losses* in groups refers to the losses identified in the efficiency of group work when measured against the possible individual contributions of the group's members. There are a number of reasons that coordination losses can occur, but two seem particularly pertinent to this thesis.

One reason that coordination losses can occur is because of a lack of common ground (Clark, 1996). To overcome these gaps in shared understanding, group members have to engage in teamwork activities at the expense of taskwork activities, e.g. working out what each other's abilities are and how these relate to any identified activities.

A second reason that coordination losses can occur is because group members have to engage in task planning activities, such as scheduling and coordination, at the expense of activities that more directly lead to the completion of the task. An example of this is in the jigsaw study, where the group members can't all work on the same pieces, so they need to identify sub-tasks that allow them to divide the pieces without getting in each other's way.

Both these reasons for coordination losses fit within our concept of disruptions in collaborative flow. Whilst both types of activity build towards overall improvements in group effectiveness and lead towards task completion, they are both outside the set of activities that directly lead to task completion, so the less time required in servicing these group needs, the more time available for direct taskwork.

6.3.6 Ringlemann effect

The *Ringlemann effect* is the loss of efficiency as a combination of both free riding and coordination losses. Ringlemann's theory relates directly to additive tasks (Kravitz and

Martin, 1986), i.e., tasks where adding a second pair of hands should, at least in theory, double the output.

For problem-solving groups, particularly groups that are attempting to solve complex or unstructured problems, the additive nature of the task may be difficult to unpick. However, unless group members are added arbitrarily, there will at least be some tacit understanding of what their expected contribution will be. This means that, at some level, the members of any problem-solving group can be assessed for their expected value towards their group and towards their group's task; this can then be evaluated against the actual performance of the group members.

It is easier to talk about the overall efficiency loss in terms of the Ringlemann effect, rather than to try to distinguish between the causes, which may not be apparent. If groups can try to compensate for efficiency losses in general, then they have a means by which they can improve their overall effectiveness. By reducing these efficiency losses, it is possible for the group to improve its collaborative flow.

6.3.7 Relevant factors

By reviewing a number of widely used group dynamics, the thesis has drawn out the domain that is covered by the term *disruptions in flow*. Of particular interest is the various inefficiencies introduced by coordination losses, with production blocking also being a particular type of coordination loss – i.e. it is something that is introduced simply by more than one person having to coordinate their activities in a group setting. It will be shown how these affect collaborative flow in subsequent chapters, but first – in the following section – an argument is presented on how they might occur.

6.4 How disruptions in flow occur

Disruptions in flow can occur within groups prior to and throughout any type of human-human interaction, whether the participants in that interaction are co-located or communicating via some instance of groupware. The disruptions can be caused by absence from prior meetings, work that has taken place between meetings, sub-group work within meetings or general misunderstandings.

Generally, the disruption in flow increases over time when group members are working independently of each other towards the same goal, regardless of whether they are co-located or not. However, this disruption does not increase or decrease in a linear manner over time; instead, the amount of independent work determines the distance between shared understanding.

For example, a work group might not see each other for a week or more, but if no one has worked on their shared task, then there may be no disruption in flow at all (or no more than existed when they separated at the end of the previous co-located meeting). However, whether a difference in understanding has developed or not, the temporal gap still has to be acknowledged; as Sarmiento and Stahl (2007) noted: 'when teams sustain their collaborative work of multiple individual sessions, the task of recommencing knowledge-building activity becomes an issue that the participants have to address' (p42).

At the other end of the spectrum, a group member might lose concentration in a meeting for only a couple of minutes, but if these were critical to making progress with the shared task, a significant disruption in flow might occur; also, within small groups, people deliberately do things individually while participating in collaboration (Arvola and Larsson, 2004).

While meetings are taking place, disruptions in flow can occur when one group member interrupts an ongoing activity before it has been resolved to a point where those taking part in the activity all understand it in the same way. Previous studies (e.g., Czerwinski et al., 2004) have shown that the majority of switching between activities in a co-located environment is caused by external interruptions, rather than the choice of those taking part in the activity. The effect on the amount of disruption caused depends upon the moment chosen for the interruption (Adamczyk and Bailey, 2004), but interrupters rarely consider this.

A disruption in flow in task-oriented group work, if unchecked, could have a negative impact upon group efficiency. The group can lose cohesion and time spent carefully breaking the task down into individually achievable activities can be wasted, because the disruption of flow prevents the outcomes of these activities being reconstructed into a coherent progress towards the group's main task.

However, addressing a disruption in flow is more than a teamwork activity of self-repair; it could be a creative opportunity that allows both parties involved in the disruption in flow to use a re-connection activity to introduce new ideas and insights into the ongoing taskwork.

The process of managing disruptions in flow within the group can also help to reduce the risk of taskwork being adversely affected by *groupthink* (Janis, 1982). In particular, the problems of self-censorship and the illusion of unanimity are addressed. An episode of self-censorship within the group can occur because there is not understood to be an acceptable way of expressing doubts about what is thought to be the group consensus. Addressing a disruption in flow, genuine misunderstanding or a lack of shared understanding, can unfreeze the group from this state and allow them to use the re-connection activity to find a course of action that holds genuine consensus. The illusion of unanimity can also be broken by managing disruptions in flow that occur as a result of misunderstandings, preventing the extreme cohesion within a group that robs it of room for manoeuvre and takes away the opportunity for members of the group to creatively change the approach that the group is taking in attempting to complete its main task.

6.5 Repairing Disruptions in Flow

In general, groups need to repair disruptions in collaborative flow in order to progress the tasks that they are attempting to complete. When the group is not in flow, either some group members become stuck, or the activities that they are performing become out of step, either with each other or with the overall task goal, and this means at that point not everyone is collaborating (in the sense that they are not all working towards a shared goal).

To correct the disruption of flow, the group members need to establish a connection that closes the gap in understanding. This process increases the common ground (Clark, 1996) between group members and the shared knowledge becomes a group-owned artefact (Stahl, 2006) that they can draw upon in the future. A disruption may be corrected either explicitly or implicitly: by this, the thesis means that to correct a disruption explicitly several group members have to perform a catch-up activity, but a single person can also unilaterally bridge a gap in understanding without interrupting others – this would be an implicit connection.

An explicit connection can be made through either direction or negotiation. A directed connection is made when one member or sub-group informs another how to proceed and this connection is accepted by both parties. If it is less clear, or not accepted, that one party has the correct information to make the connection, then how this is achieved needs to be negotiated.

An implicit connection can be made by an individual by observing and listening to other group members until they have a shared understanding. An example of this was observed in the flora and fauna study: in one of the group meetings, a participant turned up late (by around 15 minutes) and the other group members, other than acknowledging his arrival and a bit of chiding for his tardiness, continued with their previous discussion. The latecomer's approach was to sit and listen for a short while until he understood what the conversation was about. He therefore made the connection without disrupting the remainder of the group.

6.6 Conclusions

In this chapter, the thesis has introduced the idea of flow in collaboration, an idea that draws from Csikszentmihalyi's (1996) criteria for an individual in flow and Sawyer's (2003) extensions of this into group flow. It is suggested that collaborative flow not only represents the ideal for harmonious and efficient collaboration, it represents a state that must be achieved at some point during a collaborative activity for effective collaboration to take place. By this, it is meant that any group that completes a task, or even makes some progress towards completion, will have points in their group work where there is identifiable collaborative flow. If the group members get more experience at working together, or are more experienced at the task, then these periods of collaborative flow may become more regular – and the overall task time may drop as well.

The thesis has also described the problem of disruptions in flow – that is, once a group has reached a point where there is collaborative flow, this can be disrupted by a variety of means. The mechanisms by which these disruptions are caused and repaired are important when trying to understand how long-term support can be given to collaborating groups.

To test these theories of flow in collaboration, the next chapter reports on a study that is designed to separate the effects of teamwork from the effects of taskwork. The purpose of this is to then analyse those differences to see, in a relatively simple task, where contributions to collaborative flow are made.

7 A Study of Flow

> Skilful actions are spontaneous, taken for granted, and automatic. The skilled individual pays little conscious attention to producing such actions.
>
> Chris Argyris (2000, p421)

The previous chapter discussed what it means for a group to be in flow, and in particular the benefits of a group being in collaborative flow; further to this, it discussed how disruptions to this flow may occur and how a group may repair these disruptions.

This chapter introduces an experiment designed to enable the analysis of collaboration at two different levels, and look for the patterns that will support the existence of collaborative flow and what such a state gives to a group that holds a shared goal. The two levels of analysis of interest are those of task and activity, i.e. at one level looking at what the groups do as a whole (the task) and at another level looking at the small steps they make as they progress towards their goal (the activities). Within this, the analysis makes the further distinction between taskwork and teamwork.

7.1 Pilot Study

To help focus attention on promising areas for observing collaborative flow, within the domain of small co-located problem-solving group collaboration, a pilot study of a relatively simple collaborative task was run first. The purpose of the pilot study was to test that the task was viable, and sufficiently rich to analyse for flow, without being excessively complex. For this reason a task with a clear, simple structure was chosen.

7.1.1 Study

Three groups of students were asked to perform a card sort of two packs of playing cards, which had been shuffled together; one pack had red backs and the other pack had blue backs. The groups were respectively of two, four and six participants. The preference for the subsequent main study was four participants, as this matches the number in the more complex flora and fauna study, which was introduced in Chapter 5. However, because this was a pilot study, it was reasonable to see if there was anything of particular interest from varying the number of participants for a simple task.

The environment was the University of Bath HCI laboratory, which offered the opportunity to make audio and video recordings of the groups attempting the task. A room-wide video of the groups working and a narrow view of the tabletop were recorded simultaneously. Three microphones were placed around the table and their output mixed.

The participants for each group were asked to stand around a table whilst the task was explained to them. On a board to the side of the table there was a poster with eight lists of suits in a semi-random order (Figure 7.1). The groups were told that they needed to place the cards on the table in the same order as the poster, with no cards touching each other; the decision on whether to sort into packs was left open.

♥	♣	♦	♠	♥	♣	♦	♠
A	6	4	9	6	7	6	3
10	K	J	A	A	K	3	A
7	5	2	8	5	9	5	9
Q	9	6	Q	Q	5	7	Q
2	4	3	2	10	2	8	4
4	10	A	7				
8	J	K	5	7	A	2	K
J	Q	Q	6	8	3	4	2
6	2	5	J	K	8	10	5
K	A	10	4	2	4	A	10
5	3	7	K	4	J	K	6
3	7	9	10	J	10	Q	J
9	8	8	3	9	Q	9	7
				3	6	J	8

Figure 7.1. Poster used in the card sorting task

7.1.2 Analysis

The video data was analysed by categorising events into those shown below in Table 7.1. The purpose of the activity can be either taskwork or teamwork. These categories are drawn from the previous work on task breakdown in this thesis (Chapter 5), and were designed to further explore the parallels between simple and complex tasks.

Table 7.1. Categories of taskwork and teamwork used for the pilot study video analysis

		Activity Purpose	
		Task	Team
Activity Type	Planning	Two or more group members plan how to progress the task without an initial clear idea how to do so.	Two or more group members plan how to organise the team without an initial clear idea how to do so.
	Negotiation	Two or more group members negotiate how to progress the task after one proposes an idea.	Two or more group members negotiate how to organise the team after one proposes an idea.
	Enquiry	A group member asks a specific question about how to proceed with the task, which is answered by another group member.	A group member asks a specific question about how the group is organised, which is answered by another group member.
	Direction	A group member tells one or more other group members how to proceed with the task and this is accepted and actioned.	A group member tells one or more other group members how to organise the team and this is accepted and actioned.
	Activity	A group member performs taskwork based upon earlier discussion.	A group member performs teamwork based upon earlier discussion.
	Inactive	A group member is not working.	

When the video data was analysed using these categories, it was found that there was very little evidence of teamwork activities taking place, which raised the question of why this might be. One reason might be that the categories themselves were insufficiently rich for capturing teamwork, as they were developed from a study of taskwork. Related to this, is the problem that there often appeared to be more than one thing going on at once – e.g. someone could be laying cards on the table and discussing the next step with another person. Finally, it is possible that because teamwork is a developing activity in a group, it was too difficult to see it in one short task (this possibility is expanded upon in the main study, where repeated trials gave a better insight into how to identify teamwork in short tasks).

The three groups, despite their different approaches to the task, all chose from a finite pool of activities and implemented them. A generic profile of the steps of the task is:

1. Uncover poster
2. Decide how to sort cards into piles – then action
3. Decide how to split cards between participants – then action
4. Decide how to lay cards on table – then action
5. Decide how to check laid cards match the poster – then action

Drawing out this list of plausible routes through to task completion supports the earlier supposition that this is a relatively simple and well-bounded task. It was important to confirm this in the pilot study, as it would be important to fully understand the impact of any variations in the main study; with a complex task this would be too difficult, as the effects of variations would be uncertain.

The times taken for each group to complete the task are shown in Table 7.2.

Table 7.2. Time to complete task for each group

Number of members	Time to complete task
2	7m 18s
4	6m 31s
6	5m 50s

The overall time taken to complete the activity was roughly inversely proportional to the number of participants in each group. This result is slightly skewed by the fact that the group of four did not check the cards at the end of the task, whereas both other groups did. Taking into account the number of participants in each group, the total time expended was as follows: group of two – 14 minutes and 36 seconds; group of four – 26 minutes and four seconds; and group of six – 35 minutes.

These timings suggest that the task is influenced by the Ringlemann effect (see Chapter 6), i.e. the group of four did not perform the task twice as fast as the group of two and the group of six were not three times as fast as the group of two. Possible reasons for this are that either critical path activities cannot be split to be performed in parallel and/or teamwork activities are present in some form.

7.1.3 Conclusions from the pilot study

The observations from the pilot study suggest that within the relatively simple task of card sorting, there are points where the groups are inefficient – e.g. they need to discuss and work out what they're going to do at each stage; there are points at which the groups are ineffective – e.g. they make errors in letting cards touch each other, etc.; and, there are points both when the groups show some signs of flow, and others where this seems to be disrupted.

As the thesis has shown, splitting teamwork from taskwork was particularly problematic in this task, so the full study was developed to separate out the effects of these two types of activity.

7.2 Full Study

The findings of the pilot study raised many questions that with further research might lead to insight into understanding of flow in collaboration. It was decided to focus attention on the effect of group learning, as real world groups have often worked together before on identical, similar or different tasks. The purpose of the main study was to identify how collaborative flow changed over the repeated trials; also, in the qualitative analysis, some exemplar trails are linked back to the taskwork model (Chapter 5), to gain further insight into its applicability and its relationship to collaborative flow.

The study was designed around five groups of four people. In a single session, four of these groups would perform 12 repetitions of the task (13 in the case of group four) in the pilot study, i.e., sorting two packs of cards into an order provided on a poster; the posters were in colour and roughly A2 in size; the one variation was that there was a different poster for each iteration, and the posters all showed slightly different configurations of cards. Then, as a final task, they would do something different.

The task that was selected as the 'off', or non-standard, task was for them to complete four different small models from prepared pictures, using Lego-like building blocks (see figure 7.2). The models were of uneven difficulty, so there were opportunities within the task to both distribute individual work and to collaborate.

Figure 7.2. Example of completed Lego-like puzzles

The fifth group of four participants did the reverse of the other four, in that they did 12 repetitions of the building block task, followed by a single repetition of the card-sorting task.

Following on from these sessions, individual representatives from groups one to four (i.e., those who had performed at least 12 repetitions of the card sorting task) were randomly selected and formed new groups with one member from each. These groups were then asked to perform one further repetition of the card sort task. Two of these further groups were run, which will be referred to in this thesis as groups six and seven.

The purpose of running trials with these permutations was to separate the effects of repeatedly performing the same task from the effects of repeatedly collaborating with the same people (i.e. taskwork versus teamwork). To better express these permutations, the following notation is used: C_n represents n collaborations with the same group and Ta_n represents the number of repetitions of Task a (the card sort).

From the explanation above it can be seen that there was at least one instance of each of the permutations from the study, as described in Table 7.3, to compare and contrast.

Table 7.3. Task instances that separate teamwork experience from taskwork experience

C_1Ta_1	The group members have no experience of the task and have no experience of working together. This is represented by the first card sort by all of groups one, two, three or four.
$C_{13}Ta_{13}$	The group members have extensive experience of the task and have extensive experience of working together. This is represented by the final card sort of group four, and is the reason that they perform 13 sorts, rather than the 12 in the other groups.
C_1Ta_{13}	The group members have extensive experience of the task, but no experience of working together. This is represented by the task performed by both group six or group seven.
$C_{13}Ta_1$	The group members have extensive experience of working together, but no prior experience of the task. This is represented by the final task performed by group five.

The groups' activities were recorded in the University of Bath HCI laboratory with two cameras to give near and far focus and three microphones, all mixed to a single recording for later analysis. At the end of each task still photographs were taken of the group's output, so that it could later be checked for errors.

The errors that were expected from the card sort task were cards touching each other on the table, or cards in the wrong order. The errors that were expected from the building blocks task were errors in the shape of the model, or errors in colour. The end of each task was marked by one of the group members ringing a bell, so another potential error would be that this would be rung prior to all work ceasing on the task. Using the Poole et al. (2004) classification (described in Chapter 2), this study is based on the functional and temporal perspectives.

7.2.1 Descriptions of Exemplar Card Sorts

This section presents some vignettes that give a flavour of the activities taking place in the repeated card sorts. The purpose of this is to provide a natural language description of the types of changes that took place between the different categories of teamwork and taskwork experience. Also described are some intermediate phases in the learning curve, to illustrate how collaboration changed within the learning groups.

Task 1 of Groups 1-4 is described first. These are examples of a group that has not worked together before, or attempted the task of card sorting before. Prior to the study, it was expected that this would be the worst performing iteration, because of the absence of either type of experience for the group members to draw upon. Next, Task 2 of Groups 1-4 is described. These were the first iterations where group members had direct experience of both task and team to use in the development of new strategies. After this, Task 12 of Groups 1-4 and Task 13 of Group 4 (all card sorts) are described. These represent the iterations where the maximum observed experience of taskwork and teamwork could be brought to bear on the task; prior to the study, it was expected that these would be the best-performing iterations of the task, because of the presence of that prior taskwork and teamwork experience.

In addition to the first four groups, also described are the card sorts for Groups 5, 6 and 7. Group 5 attempts the card sort after 12 attempts at the building block task, so they have teamwork experience but not taskwork experience. Groups 6 and 7 are the groups formed of representative members from Groups 1-4, consequently they have taskwork experience but not teamwork experience.

Group 1, Task 1

One participant takes the poster and the other group members gather round the table. Another reads out the instructions; having done this, he tries to sort the cards and the others observe. He suggests starting with eight columns (i.e. just laying the cards according to the poster pattern, without any prior sorting) and asks for other ideas. There are no other ideas presented, so they all start sorting cards.

They discuss how to place the cards (lengthwise or breadthwise across the table), as they're not sure how the cards best fit. They make their decision and carry on sorting. One of them comments on the number of tasks they have to do, and they share a joke about it. As they progress, someone suggests that they check the order and this leads into a point where they discuss the strategy again.

They all continue to lay cards and one person corrects another when they make the mistake of putting touching cards together. After they have been moved, she confirms that the changes are ok, and another suggests that two of them start on the other side of the table.

As they progress, they are explaining to each other what they're doing. They realise that there are duplicate cards (i.e. 2 decks) and so they organise themselves into pairs working either side of the table. As they near completion, they check the instructions and discuss whether they have completed the task properly - then they ring the bell to signal completion. Their completed work is shown in figure 7.3.

Figure 7.3. Sorted cards after the completion of Task 1 by Group 1

Group 2 Task 1

The group members all read the instructions. One of the instructions mentions the availability of Bluetak and pins, and one person asks what the Bluetak and pins are for – at this stage, the others don't know. They confirm the detail of the task, e.g., one says, "So, two decks, I assume".

They discuss their strategy. One suggests a method where each takes some cards and lays them according to the pattern on the poster. Another suggests an alternative method by saying "or we could sort them into groups first", and this is accepted. They continue to discuss the rest of the task as they do the first sort (into suits).

Once sorted, one suggests the next step – which is to lay the cards in rows – the others agree. One confirms with the others what is required by demonstrating how he is going to lay his cards; again, the others agree and they start laying the cards into rows. They need to avoid each other as they're laying the cards, so there is repeated negotiation for space (or apologies for collisions, etc.).

They all finish except one who has only laid half of his allocation – no one helps him. The others check that no cards are touching each other. When they are all finished, someone asks the others to confirm that their own rows are ok, saying "Does everyone want to check their row?". They check, say "ok" and ring the bell.

Group 3 Task 1

First, all the group members read the instructions. One suggests which way they lay the cards on the table, and also suggests "Shall we split the cards up?" Some of the others are talking about something else and so he has to make the same suggestions again. This time, they agree and start, noting that there are two decks. They discuss whether to pin the poster up or not, agree and one does that.

Someone suggests that everybody continue by laying one column. They agree to this and confirm the direction that they're going to lay the cards, and which suit each is doing. They change the way that they're laying the cards after another suggestion.

The first person finishes and tells the others, but then stops without helping anyone. Shortly, someone notices that there is a big space between suits and they agree to move them closer together (even though not in the instructions).

Near the end, one person is still laying their cards, so others check theirs order against the poster. Finally, they all check at the end that the cards aren't touching each other and someone rings the bell.

Group 4 Task 1

All the group members read the instructions. One begins the task by passing a few cards to each of the others – although he gives no instruction as to what to do with them. Another directs everyone to turn over their top card, and demonstrates that the pattern can be copied by doing this and then placing individual cards. For a while, they place cards randomly on the table.

Someone tells the others they'll have to place them lengthwise, while another checks the instructions again. They discuss again which direction to lay the cards and then they start to lay cards without any prior sorting. This causes some confusion; for example, at one point someone removes a card in the wrong place saying "That five shouldn't go there". Shortly afterwards, two of them realise they're mixing suits and have to rearrange the laid cards.

Also, they haven't split the cards evenly, so eventually someone runs out of cards and asks for some more; this happens twice.

Once the cards are down, they rearrange them and check the order. One asks "Do they all have to be lined up?". When told no, he says "Ring the bell!"

Group 1 Task 2

This time the group members begin by organising the artefacts to where they were at the end of the last task. One of the group members reads out the instructions. They discuss and agree a new strategy, seemingly to agreement but then one asks what they are doing, another explains and they all discuss the new strategy some more.

They then split the cards into suits before someone instructs the others to lay one suit each. This is not accepted implicitly – first they discuss how this works as a method – then they all agree and do it.

Someone asks which way around they are laying the cards (i.e. the direction of the suit order, so that they match the poster). Once they have agreed this, one needs to move another's cards to have space to lay his. Later, a group member realises that he's behind and asks for help. They also discuss again where to lay the cards, so the suits are in the same order as the poster.

Near the end, one group member is left with cards still to lay while the others wait – while he's doing this the others discuss a better strategy for next time.

Group 2 Task 2

The group members read the task and confirm that it's the same as before. Someone asks whether they're going to use the same strategy or change it. They decide that it worked ok, so start to do the same (splitting into suits). Once the cards have been sorted into suits, someone confirms that sorting into the poster order is next. Three of the group members do this in their hand, the fourth lays them straight down onto the table. As they're doing this, one suggests moving the poster so that they have more space.

They discuss whether sorting in hand or on the table is the better method; one says of lying them on the table "it's better because you can check the order as you go along". They also discuss what can be done when someone finishes before the others; someone suggests "perhaps anyone finished can shuffle them to make sure there's none touching".

When all the cards are laid, someone asks "done?", and another person quickly confirms they've all checked their rows, then presses the bell.

Group 3 Task 2

The group members confirm it's the same task and put the artefacts in the same place as the first iteration. They sort into suits, without discussing the plan. One confirms, "so, same thing I guess", before they lay the cards. The others affirm and they carry on. They stop to discuss whether to lay the cards lengthwise or breadthwise, but stick with their original plan and lay the cards as before.

Near the end of the task, one reflects, "it seems to be quicker". As soon as the last card is placed someone asks "Is it done?". The slowest person checks and says "Yes" and they ring the bell.

Group 4 Task 2

The group members read the instructions and confirm that it's the same task. Someone starts by suggesting splitting the cards into suits, which they then do. One suggests that two of them do each pack, and again they agree.

They are operating as complete sub-groups, one pack each and begin by laying the cards out in suits. One asks his partner "shall we lay them out like they're doing?" One side realises that it is faster to sort the suits before laying them out and does this; the other pair does not. One pair finishes first and checks the cards; when the other two finish as well, they all rearrange the cards and check again, before someone presses the bell.

Group 1 Task 12

While waiting for the task to start the group members were discussing their background (demonstrating both teaming and group development). Once presented with the task, they put the artefacts in the same places as previous trials.

Their settled method is now so honed that they can chat while they're working, but the card sorting method is performed without any direct communication. They also assess their performance against the first task: "Yeah, we definitely made a mess of the first one, didn't we – sorting cards".

There is one point in the task where one group member tells the others that he's missing two cards and one of his colleagues helps him find them. Near the end of the task two of the group are without work, so one offers to help another still working, saying: "Shall I do the bottom half".

Group 2 Task 12

First, the group members move the artefacts to where they were in previous iterations. One quickly checks the instructions, confirms that they're the same and then they get on with their chosen method. Two sort cards in hand and two sort and lay cards (this is a result of teamwork activity to avoid getting in each other's way). After laying all their cards, they check the order without being asked this time, and there is no wait or confirmation before the bell is rung.

Group 3 Task 12

The group members put the artefacts in the same places as before, and get straight on with the task as per previous iterations. They reflect on the number of times they've done the task (perhaps showing some signs of boredom). At some point, the poster falls down and one has to put it back - otherwise they lay the cards in silence. Near the end, those who have finished move the cards nearer together, while the slowest is still laying the last few.

Group 4 Task 12

No one in the group checks the instructions, just go into the method that they've been repeating. They sort into packs, and then each pair takes one pack and sorts it into suits. They each lay one suit from the pack they sorted, and then they lay a second. The cards are rearranged as they're checked at the end.

Group 4, Task 13

In this case, the group acknowledge the task is the same again. Then they silently sort and lay the cards, using the strategy that they have developed in earlier iterations. The only interation between members, once they have their own cards, is to avoid each other as they lay them. At the end, one group member waves their arm above the bell as an enquiry to the others – i.e., are we finished? – the others nod, and the bell is pressed.

Group 5, Task 13

The group have no prior experience of this task, so on receiving it they all read the instructions. One person takes the cards, and another suggests 'everyone take a suit?'. This results in the person holding the cards sorting the entire lot into four suits on the table. As they haven't shared this activity, the group have plenty of time to discuss whether they will lay the cards lengthwise or breadthwise – one person takes a few cards to see if they will fit across the table – she confirms that they will, so they choose that as their approach.

Before the person sorting the cards into suits has finished, each of the others takes a few cards from different piles and begins to order them according to the poster. They discuss pinning the poster, initially deciding that they don't need to then changing their mind. They put each suit in order in a pile across the table to match the eight suits in the poster, but then wait for all suits to be ordered before laying them out – this results in three of them watching the fourth person for some time, before they finish. Having done this, it is a simple matter of each of them laying out two suits of cards. At the end they check the order and look for touching cards before someone rings the bell.

Group 6, Task 1

On receiving the task, all four group members read the instructions before one says: 'Ok, so it's exactly the same', to which someone else says 'Yes'. Having established this, the group members need to tell each other how they've started the task before: one explains that he put the poster on the wall at the start; another says that he sorted the cards into suits. Both these ideas are accepted without challenge and they start sorting cards.

However, immediately three of the group members start sorting the cards into suits, whereas the fourth begins to sort her quarter into packs (i.e. red or blue backed cards). After a few moments, another group member notices this and points it out to her. As the other three are all following the same but different strategy, the onus is upon her to change and comply – which she does to an extent. She now sorts into four suit piles of her own, whereas the other three all sort onto the same piles.

Once the cards are sorted, one group member says ‘I’ll be Spades then’, taking that pile of cards – there is no negotiation. The others each take the suit nearest to themselves. The person that took the Spades cards now explains how he sorts the card order within the suit (he does it in hand before laying them on the table); another says ‘I do that, yeah’. The other two don’t answer, but follow the same strategy.

When the first person has sorted their cards, they ask another ‘how did you lay them out?’ meaning lengthwise or breadthwise on the table. The other person says ‘that way’, pointing lengthwise and that’s how the cards begin to be laid. The other two group members aren’t consulted, but comply. They all know that the cards should not touch, so there is some checking without any discussion; someone says ‘are we happy with that?’ and getting approval rings the bell.

Group 7, Task 1

This group begins less carefully. One group member says ‘Oh, what a surprise!’ on seeing the cards. Another immediately pins the poster on the wall, without consulting the others and nobody appears to read the instruction sheet. They begin discussing how they will start the task, again drawing upon their experience from their previous groups. Like Group 6, they settle on sorting the cards into suits and also like Group 6, they end up doing this in a mixed fashion – two sorting cards into the same piles and two into different piles.

Once they have the cards in suits, like with Group 5 someone suggests that they sort the cards for a suit each in their hands. At this time he also tells the others that the cards should be laid lengthwise down the table. Both ideas are accepted and they start to sort the cards. Once this is established they sort and lay the cards in silence, moving around the table as necessary. When the cards are nearly all laid, someone says ‘they weren’t meant to be touching either’, which leads the others to recheck their cards – then they press the bell.

7.2.2 Quantitative Analysis

In this section, the thesis introduces the quantitative data collected in this study and analyses it to show how it supports the theories of flow that have been proposed.

Groups 1 to 4

Figure 7.4 shows the times for the first twelve trials for each of groups 1-4. It illustrates that each of the groups follow roughly the same profile for improvements in the times that they took to complete the task. The times were recorded by the author of this thesis from observations of the video data; these times were confirmed by an independent observer, who placed all the start and end times within a maximum of two seconds difference. The start point for each activity was taken to be when one of the group members first touched an artefact provided for each task; the end point was taken to be when one of the group members rang the bell.

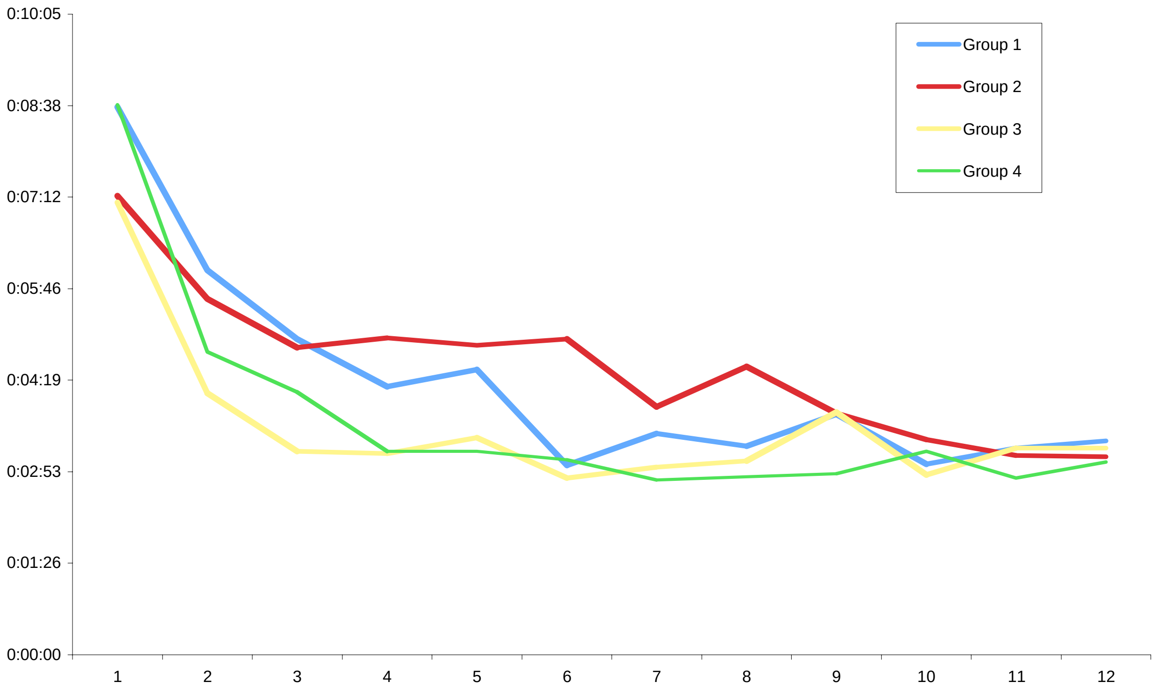

Figure 7.4. Time taken for each group to complete each repetition of the task

To analyse the variance between these four groups, Anova model R-I was used, which is typically referred to as a 'treatment x subjects' design (Meyers and Grossen, 1978). In this analysis, the different groups are treated as the independent variable (i.e. the subjects) and the repeated card sorts – tasks 1-12 – are the dependent variable (i.e. the treatments, which in this case are the timings). To do this, the times taken for each task were recorded in seconds (see table 7.4).

Table 7.4. Task times (in seconds) for groups 1 to 4

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12
G 1	479	360	273	257	267	185	212	220	227	185	196	201
G 2	432	332	291	301	289	296	238	268	220	203	188	188
G 3	421	247	193	188	203	168	179	186	229	174	196	198
G 4	515	283	245	189	191	182	164	165	168	190	165	181

The results from the Anova are shown in table 7.5.

Table 7.5. Anova R-I summary for groups 1 to 4

ANOVA Summary				
Source of variance	SS	df	MS	F-ratio
Treatments	264219.2	11	24019.92	0.111924
Subjects	957817.3	3	319272.4	
Treatment X Subjects Interaction	7082104	33	214609.2	
Total	8304140	47		

The low F-ratio indicates that there is no significant difference between the task iterations over Groups 1-4. This is what was expected, given the number of similar iterations once the groups have developed a workable strategy for the card sort.

As well as the times taken for the groups to complete the repeated task, consideration was given to the number of errors that they made. Primarily, these were errors where the group claimed to have completed the task while cards were still touching each other on the table. In table 7.6 are the number of errors that each group made (described as instances) and the total number of cards that this involved.

What this shows is that each group has its own standards for quality - Group 3 was particularly poor. This provides more evidence that a group can only work to its own standards, so it can still be said that group 3 was in collaborative flow at times, even though by the standards of the other groups they were relatively ineffective.

Table 7.6. Touching cards, as instances(cards), for groups 1 to 4

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10	Task 11	Task 12
G 1	-	-	1(2)	1(2)	1(2)	-	-	-	-	-	-	-
G 2	4(10)	-	3(6)	-	-	-	-	-	-	-	-	-
G 3	1(2)	2(5)	5(10)	3(6)	2(4)	8(18)	4(8)	2(5)	6(13)	4(8)	1(2)	1(2)
G 4	1(2)	1(2)	1(2)	5(10)	-	2(4)	-	-	1(2)	-	-	-

These findings also show that group effectiveness does not relate to flow in collaboration when it is taken as an external measure, i.e. observed and measured by someone outside the group. Although this is the only sensible way of measuring the group's real effectiveness, their ability to flow in collaboration appears to relate more closely to their self-perceived effectiveness. That is to say, when the group members believe that they are being effective with respect to their task, then they will have good collaborative flow.

Comparison to Group 5

The correlation coefficient for the curves of the mean times for groups one to four and the time for group five is 0.966114. This represents a very strong correlation, as can be seen in Figure 7.5.

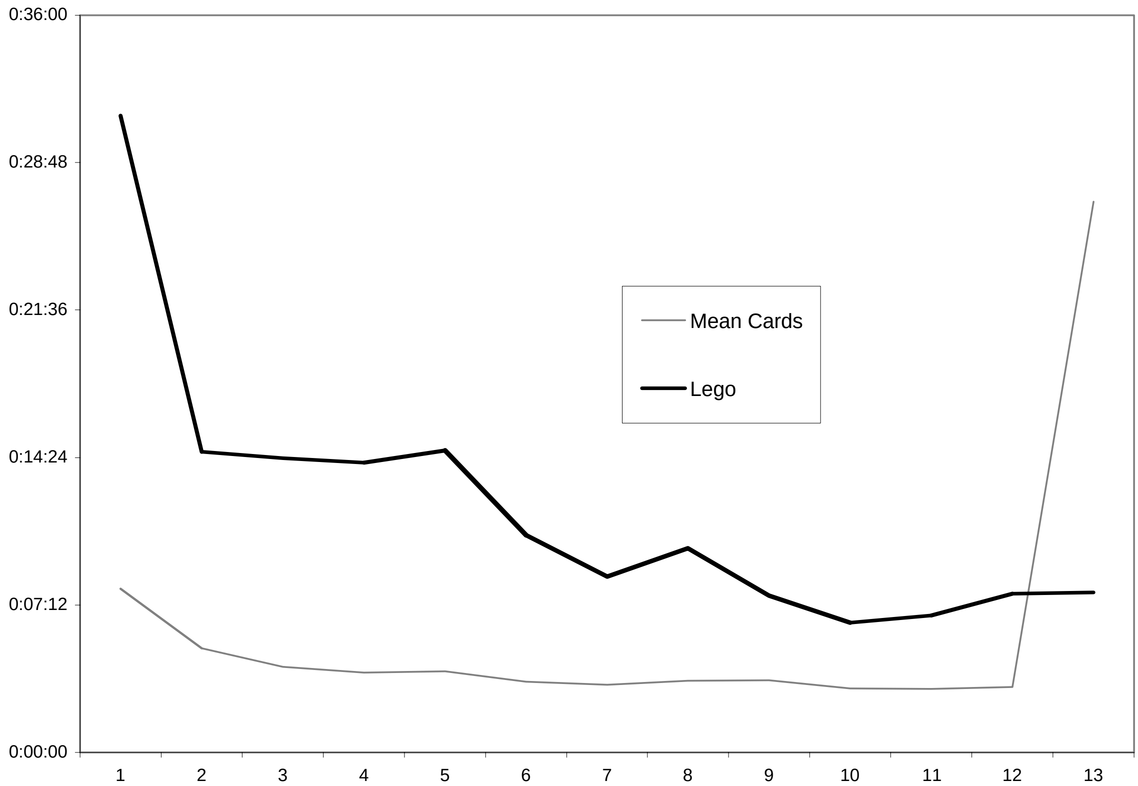

Figure 7.5. Mean card times v Lego times

The strong correlation between the card sorting groups and the lego building group was interesting, because the lego building task was clearly much harder (in the sense that the groups took much longer to complete the task, regardless of whether they attempted it 12 times or only once). Also, there are clear 'step changes' in the lego building task – ie, clear differences between iterations where the group does something different that results in a significant change in the time taken.

Observing these led to a search for the same profile in the card sorting groups. The steps are less obvious in the card sorting task – the changes in strategy are minor, and the time gains small – but they do exist.

For all groups, between the first and second iterations there is a major time saving on completing the task (Figure 7.5). There are observable savings in both taskwork and teamwork. Up front, the group does not have to work out a complete strategy for a new task – once they realise the task is almost identical to the previous one, they deploy their existing strategy and negotiate more minor changes as they go ahead.

The main step change in the group repeatedly lego building (group five) was when a second member began to help earlier on the most complicated of the four models. This dropped the average completion time by 3-4 minutes and instantly made the second most difficult model the time-limiting factor. This effect of reevaluating the last outstanding task was also to be seen in the card sorting task and showed an interesting overall approach to repeated learning tasks.

The general pattern was that in the first iteration, there was a lot of planning, followed by an attempt at the task with some minor adjustments along the way. For the next few iterations, the groups continued to make changes, individually and as a group, until they were relatively satisfied with their approach. After this phase, they generally continued with the same strategy, but at the end of the task there was usually some uneveness in task distribution, ie, someone was left working when the others had finished, and this was the activity that remained in focus throughout all the iterations of the task. This may lead to the step change time gains in later iterations.

Groups 6 and 7

As groups 6 and 7 only performed one card sort, the thesis needs to establish whether there was any difference in performance between these efforts and the overall efforts of the first four groups. Because of the small sample sizes, the Kruskal-Wallis One-Way Anova was used, which is a non-parametric equivalent of the standard Anova test (Meyers and Grossen, 1978).

Table 7.7. Kruskal-Wallis One-Way Anova rankings

Trial	Mean Groups 1-4	Rank	Group 6	Rank	Group 7	Rank
1	479	14	254	12	245	10
2	305.5	13				
3	250.5	11				
4	233.75	8				
5	237.5	9				
6	207.75	7				
7	198.25	4				
8	209.75	5				
9	211	6				
10	188	2				
11	186.25	1				
12	192	3				

Using the rankings in table 7.7, the calculation of the statistic H, associated with the Kruskal-Wallis One-Way Anova, is as follows:

$n_1 = 12$	$n_2 = 1$	$n_3 = 1$
$\sum R_1 = 83$	$\sum R_2 = 12$	$\sum R_3 = 10$
$R_1^2 = 6889$	$R_2^2 = 144$	$R_3^2 = 100$

The value of H is calculated according to the following formula (where k = 3, the number of groups):

$$H = ((12 / N(N+1)) * (\sum_{i=1}^{k}(R_i^2 / N_i))) - 3(N+1)$$

$$H = 1.747619$$

Because k = 3, there are 2 degrees of freedom. For there to be a significant difference at the 95% level, H must exceed 5.99. Therefore it can be stated that, according to this metric, there is no significant difference between the performance of groups 1-4 and that of the reformed groups 6 and 7, in terms of time taken. This fits with the qualitative analysis, which suggested that the performance of the reformed groups fell somewhere in the middle of the repeated trials of Groups 1-4. The primary reason for this was that extra teamwork was required to coordinate or change the different task strategies brought by each group member.

7.2.3 Qualitative analysis

Apart from analysing times and errors, the thesis also provides a qualitative analysis regarding the change of activities from trial one to trial twelve. In analysing these trials further, some interesting comparisons were made in trying to understand the activities that change and disappear. Also analysed were a number of intermediate steps, where changes in behaviour appeared, and the off-task (thirteenth) to see which activities reappear.

Trial one

Specific to the first trial is the need to read the instructions carefully and have a look at the poster. The instructions remain the same in subsequent trials and the posters have the same form (although the patterns are slightly different). The overall effect of this is that after one or two trials the groups no longer carefully study the instructions.

Once a group's members feel that they have some understanding of the instructions, then they need to work out at least a partial strategy for completing the task. What was clear from the observations, and from the overall time taken, was that this was particularly difficult for the first task. None of the first efforts at card sorting appear to establish any sort of collaborative flow. So, why is this?

When considering Csikszentmihalyi's (1996) measures of flow in individuals as a pointer to collaborative flow, there are a number of candidate reasons that the flow is difficult to establish in the first iteration. First, they do not have clear goals defined for every step – at the start of the first task, they are not even sure what every step is, or of the final goal (certainly, they understand that they have to lay the cards on the table in an order represented by the poster, but detail needs to be resolved – for example, most groups had to discuss whether lay the cards down the table or across it). Second, there is no immediate feedback to their actions – because they don't know whether the activities they try are the correct choices, in the right order, or whether they'll fit with what everyone else is doing, then they're left with uncertainty that requires them to continually question their actions and those of others. These first two problems can be predominantly ascribed to taskwork, but these trials are of groups that have not previously worked together, so they have no norms for teamwork to draw upon either. Again, using Csikszentmihalyi's criteria, this means that there is an element of self-consciousness amongst the group members that would not exist if they were more familiar with working together.

In the previous chapter, the thesis reasoned as to whether efficiency or effectiveness were useful measures for evidence of collaborative flow. The timing evidence (presented in the next section of this chapter) suggests that the first attempt each group made at the card sort was not very efficient – typically it took them 2 to 2.5 times longer than they showed themselves to be capable of in later iterations. However, the process was ultimately just as effective in producing an outcome of cards laid in a specific order. This shows that there must be periods of collaborative flow embedded in these first efforts – because somewhere they found a way to progress the task to a successful conclusion.

The collaborative flow that is in evidence in these first attempts at a card sort seems to be present on an activity-by-activity basis. For example, the group that made the decision to sort the cards back into their two constituent packs – once they had agreed upon this decision, there is a period where the group members appear to be in collaborative flow, i.e. they have a known shared goal (albeit a sub-goal), a method to achieve it and they are working as if they are briefly focussed completely upon what they're doing.

In between these brief periods of collaborative flow are the disruptions to it – the periods where group members are not all implicitly aware of what to do next, or whether what they are currently doing is right. The disruptions in flow caused by production blocking could be observed, as sometimes group members have to wait their turn to suggest an idea more appropriate than one that has already been put forward – e.g. in group two, where someone suggests laying the cards on the table without any prior sort, before another person intervenes and suggests that they do a sort first.

What was observed in these first trials was the application of the taskwork model (see Chapter 5) in breaking down this task. Even though the task is much simpler than the one from which the model was developed, the process is effectively the same. The difference is that in this task, the group has a relatively clear understanding of the goal, but still they do not have a clear idea of the steps required to achieve it. This suggests that collaborative flow represents the periods of certainty in collaborative work that is the output from the taskwork model, which is a means of explaining the breakdown of uncertainty.

This leads to further reasoning about efficiency within collaborative work. As the thesis has established, at some level the task is performed more efficiently in later iterations, when the group are more familiar with it, more adept at it and more used to each other. However, at another level, it can be reasoned that there is no shortcut to these states and therefore a group might be said to be efficient if they are unpicking the complexity of the task as they need to.

Trial two

After trial one, there is a similar pattern for the next few trials. Each phase of the card sort, eg, splitting into suits, laying the cards, etc. is discussed as it is attempted and minor changes are made along the way. Some suggestions are taken up, some are rejected, and others are tried and then rejected if they don't work. Each distinct activity is tuned, and this peters out as the group becomes satisfied with each phase and then finally with the whole task.

In these early trials, the time reductions can be attributed to two things. First, the group members are improving the strategies for the task and for their collaboration towards completing it. And second, they are becoming more adept at the task itself, e.g., they start to sort the cards more quickly.

Referring back to Csikszentmihalyi's criteria for flow, the groups are getting closer to having clear goals for every step. Each group certainly has a method that effectively delivers the required outcome for the task, and it is a matter for the individuals involved as to how reflective they are about this method and whether they are prepared to invest more thought in how to improve it.

In these early trials it is still possible to identify particular disruptions to the collaborative flow. Mostly, group members still need to explicitly query how they are going to attempt each phase of the card sort, so there are break points for discussion. Each of these break points leads to coordination losses that break the collaborative flow, but in between there is evidence of strong collaborative flow as the aspects of the task become more familiar.

Trial Twelve

In the later trials, because the groups are satisfied with their strategy, they work flat out and no longer consider if there are any further improvements that could be made. What they now concentrate on is performing the task more quickly, simply through better execution. The only point that reflection continues to take place is towards the end of the task; if the distribution of work is uneven, then one or more members becomes free before the end – at this point they still notice if improvements can be made, so the tendency is still to make minor improvements to the final activities in the task, as these are the ones under the microscope.

What is clear in trial 12 for any group is that they have a well-defined strategy for completing the task, including how the work is distributed. In the case of the card sorting groups, this was not always the same strategy (across groups) but it tended to be consistent within groups for the last few iterations of the task. Exactly when each group decided they had an optimal strategy varied according to the group, but in each case it was well before trial 12.

In trial 12, because the group has a particular strategy they work flat out on it. Although the group work is still collaborative, because there is a shared goal, at another level it has now become a task that only requires coordination. Therefore, one point to consider from this is that very efficient collaboration can be achieved by finding ways to remove many of the established mechanics from the collaborative flow. Such an effect is not likely to be so apparent in a complex task, nor so easy to observe, but it may be true that in all collaborations some prior experience invisibly removes disruptions in flow that would otherwise occur.

Because of the repeated trials, the twelfth effort by these groups at the card sort does not represent a representative profile of task for the taskwork model – it has very little complexity, and the previous trials have added structure to it. However, in completing this trial of the card sort, groups one to four each worked through the task in a way that is consistent with the model. Given the poster, instructions and cards, they almost immediately *understand the task*; past experience tells them the *structure* of the sub-tasks, which they then implicitly *distribute* and *complete*. This shows that the model is applied regardless of whether good collaborative flow is observed.

The 'off' task

When the Lego is brought to them for trial 13, the groups can obviously see that the task is different, so again they revert to carefully reading and discussing the instructions before they proceed.

The pattern of work for the instance of this in the study seems to show all the characteristics of the first efforts of the comparable groups. There was an expectation that the extra knowledge of collaboration would have helped the group to perform more quickly. So, why might this be? One possible explanation is that the previous task had not enabled them to build sufficient generic knowledge about working together. Linked to this is the possibility that the tasks were just too different for any transference.

One possible weakness in the study is that it was not designed to ask the participants to be as quick as possible with the final trial, so another explanation for the slow trial 13 is that the group were collaborating very well together, but took time to explore the best way to complete each step. Certainly this is an aspect that needs further exploration in future studies.

Group 5, Task 13

This is an example of a group that has previously worked together attempting a new task for the first time. In this case, the group has attempted the lego building task 12 times and here attempts a card sort. The time for task was most similar to that of groups who had not worked together before. Given that there was a significant time gain for the groups that had attempted the task before, but not with each other, this suggests that prior task knowledge may be more important to performance than prior team knowledge.

Group 6, Task 1

This is an example of the task attempted by group members with experience of the task, but not with working together. The performance of this group was not as good as the best efforts of groups that worked repeatedly on the same task, but better than groups that worked together repeatedly on a different task before attempting this one.

Group 7, Task 1

This is the second group that comprised a member from each of groups 1, 2, 3 and 4. As with Group 6, the performance of this group was not as good as the best efforts of the groups that worked repeatedly together, suggesting that task knowledge alone is not sufficient for good collaborative flow.

7.3 Conclusions

The study presented here was designed to identify and illustrate areas of collaborative flow in a simple task; it had the specific purpose of separating the effects of teamwork from those of taskwork, by creating task instances where a group had, to varying degrees, experience of one or the other, neither or both (specifically with respect to the card sorting task).

The groups that performed repeated trials of the card sort and the group that performed repeated trials of the Lego-based task all followed similar high-level patterns in addressing their repeated task. In the early trials, they formed and then developed a task plan that was satisfactory to the group and then in their latter trials this plan changed very little – in some cases it did not change at all. These observations are consistent with a study by Tyre and Orlikowski (1994) who found that users of technology went through an initial period of experimentation, before settling on a method of use that they were reluctant to change.

The study showed that the removal of either task experience or team experience, from a group member who had previously experienced both, led to further disruptions in collaborative flow. This indicates that the conceptual analysis of collaborative flow can add an understanding of how teamwork and taskwork interrelate and therefore extend the understanding of collaboration on complex problem-solving tasks.

The conceptual analysis of collaborative flow indicates that groups may use a series of repeated activity types, some of which can be drawn from the taskwork model introduced in Chapter 5. Beyond those, activity types that support teamwork also need to be considered. Additionally, the study of flow highlighted that the way in which group members monitor each other's work is important to how they develop both task and team capability.

Another area of interest highlighted by this study is that, during collaborative activities, group members involved in the collaboration may also perform individual activities that are still tied to the overall collaboration. For example, two people may be sorting a pile of cards into those that are red and blue backed respectively; at the same time, one of those people is watching the other group members sort more cards. That person is performing a collaborative activity of jointly splitting the cards, but also an individual activity of monitoring the other group members' actions.

What was discovered in this study leads to a question of the wider problem of generalisability of collaborative activity between different groups of people and across different tasks. Clearly there are subtle differences between any specific instances of people working together, regardless of whether the collaboration involves the same people, or the same task, or even both of these together. However, there are also some traits in the different collaborations reported here that suggest generalisabilites can be made between different collaborations.

The next chapter introduces a new framework for collaboration that can be used to build a comprehensive picture of how different instances of collaboration can be abstracted to their main characteristics. The purpose of this framework is not only to build a more comprehensive and holistic understanding of collaboration, but also to help identify areas of collaboration that are suitable for specific technological support.

8 Collaborative Schemata

> Coming together is the beginning. Keeping together is progress. Working together is success.
>
> Henry Ford, American automobile magnate

This chapter reflects on the findings of the studies discussed in the thesis so far, to show how they provide a series of building blocks to design a useful evaluation framework for collaborating groups. The contributions made in Chapters 2-7 are reviewed and the links between them identified to show how they build into a comprehensive representation of collaboration.

Following on from this, the concept of collaborative schemata is introduced, which provides a solution for this framework. This is a two-tier (abstract and concrete) framework that allows observers to relate specific instances of collaboration with generalisable concepts that can be supported across multiple instances.

After introducing the collaborative schemata framework, the thesis argues why this is a useful tool for practitioners involved in the analysis and design of GSS systems. Two worked examples of the concrete schema are built from the card sort study introduced in the previous chapter, but the validation of this framework is complex, so the long-term route to this goal is considered as a conclusion to the chapter.

8.1 Development towards a new understanding of collaboration

Chapters 2-7 of this thesis have each focussed on slightly different aspects of collaboration, so that from them a consolidated framework that describes collaboration can be defined. Each of the different lenses though which collaboration can be viewed give some insight into how taskwork affects collaboration or how teamwork affects collaboration. Within these categories of taskwork and teamwork, the different perspectives also provide insight into how a collaborative instance could be categorised – these are the parameters of the task and the parameters of the team; alternatively, or additionally, the different perspectives provide insight into how the taskwork or teamwork unfolds during the collaborative instance – these are the activities required to perform the task and the activities required to maintain the team. The contributions of each theory are illustrated in figure 8.1.

Each of these lenses is reviewed at the start of this chapter to show how the argument for a collaborative framework has been developed in the thesis; following from this, a prototypical framework is presented.

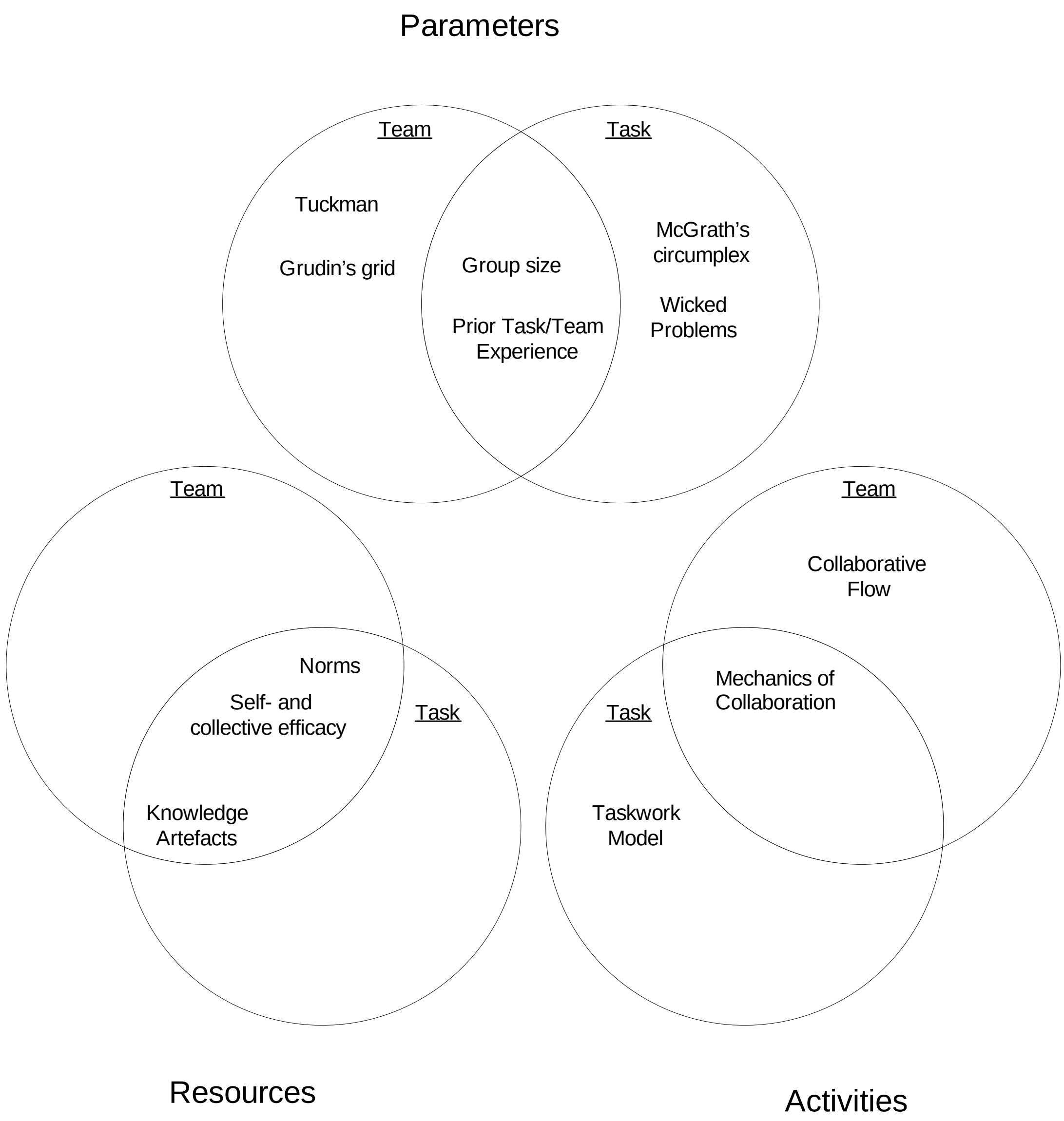

Figure 8.1. Theoretical Contributions to the Collaborative Schemata

Chapter 2 reviewed a number of concepts that are important to collaboration; in particular, the relevant theories that help support the development of a collaborative framework are: Tuckman's theory of group phase development, group norms, group size, McGrath's circumplex, the mechanics of collaboration and Grudin's 3x3 grid for categorising groupware.

Tuckman's theory suggests that groups develop through a series of identifiable phases (forming, storming, norming, performing) until they reach their optimum performance capability. It assumes that the members of the group remain the same throughout – if someone joins or leaves the group, then the 'new' group begins again at the forming stage. However, when this happens, the common ground between the previous group members often helps to carry the new group through the development phases more quickly, because there is less contention to resolve.

This theory contributes to an understanding of collaboration by showing that the nature of teamwork within a group changes over its lifecycle. The development phase of a group at the start of any collaborative task is a parameter that can be used to situate that collaborative instance in line with other comparable ones.

Related to Tuckman's theory is the more general issue of the development of group norms. Norms can be identified by group members at any stage of group development, but the main point at which they're challenged is during the storming phase, which then leads to a norming phase where acceptable compromises are made. This way of thinking about group norm development requires the group members to have the capability to define, negotiate and develop their own norms. There are, of course, norms of behaviour that are created and imposed on groups, perhaps as part of a larger organisational culture or at a societal level.

Norms that can be explicitly defined for a collaborative instance, however, are important for two purposes. Those that the group members are understood to share at the start of a session can help to situate that instance of collaboration, so that its comparability to other instances can be better understood according to the teamwork view. However, as norms are difficult to develop as a parameter (beyond Tuckman's broad phases of development), they are recorded in the collaborative schemata framework as a resource.

The theories about group size in Chapter 2 expressed the common distinction that two people interacting as a dyad was a special case, groups of three to around a maximum of seven constituted 'small' groups and groups sizes of above seven were 'large' groups and these generally had a different dynamic. Rather than labelling groups as either large or small in the framework, a decision was made to record the number of group members as a parameter. This allows users of the framework data to determine for themselves the comparability of two groups, based upon their relative sizes.

The *group task circumflex* developed by McGrath (1984) and discussed in Chapter 2, demonstrated that activities within groups are undertaken for a variety of different reasons, some of which can be made with underlying conflicting motives between group members. McGrath's circumflex is not represented directly in the framework, but it helps situate the area of group task interaction that aspects of the framework represent. Principally, the framework represents the categories of interaction that McGrath identified as collaboration; however, in McGrath's classification, conflict is seen as an alternative to collaboration, whereas in the collaborative schemata framework it can be part of collaboration. Activities such as negotiation involve conflict, as does the development and enforcement of norms – but if these activities are part of the work towards a shared goal, then they are part of a group collaboration.

The Mechanics of Collaboration (Pinelle and Gutwin, 2003) provide an interesting set of low-level primitives that can be used to describe collaborative endeavour. However, the activities that are required for a collaborative framework need to be at a higher level, otherwise it is likely to be too difficult to see the differences between different collaborative instances. This issue was addressed in this thesis and is discussed later in this review. Although the mechanics are too low level for the needs of the collaborative schemata, they did inspire the idea of developing a useful set of activities that could represent higher-level collaborative aims and objectives.

The final important pillar towards the development of a collaborative schemata framework in the literature review was Grudin's (1994b) categorisation of groupware according to time and place. Different groupware offer a group's members the opportunity to be in the same place, different but predictable places or different and unpredictable places; similarly, they may be working on shared tasks at the same time, at different but predictable times or different and unpredictable times. This provides two teamwork measures (time and place) that can be used to provide useful categorisation parameters for individual collaborative instances.

One problem in developing a collaborative schemata framework to describe collaborative instances is in understanding and representing the contributions of individuals within the group as well as capturing group-emergent properties that only exist because of the effort that those individuals put into working together. In *Chapter 3*, efficacy within groups was introduced as a concept that was both useful in better understanding collaboration, and also as a means of exploring the problem of individual characteristics, i.e. self-efficacy, and how they develop into group-emergent properties, i.e. collective efficacy in this case. The study of self- and collective efficacy supported other studies that showed collective efficacy to be a group-emergent property rather than something that could be ascertained by aggregating similar self-efficacious beliefs of the group's members.

An important characteristic of Bandura's theory of efficacy, at both the individual and the group level, is that it appears to be a factor that controls agency. By this, it is meant that a person (or a group) that has a (collective) belief that they are able to do something will be willing to at least try. Therefore, for an ability to be transferred into a capability, the agent (person or group) must have sufficient belief in that ability to use it.

From this study, it can be seen that within the framework, the transition from abilities to capabilities needs to be captured at both the individual and group levels. In the framework, this is captured as a set of 'abilities' resources; the reason for recording abilities rather than capabilities is that, as Bandura showed, factors affecting efficacy (and other factors that prevent a person being capable of applying an ability) are transient.

Considering the issue of individual and group capability further, it can be reasoned that within a collaborating group there are a mixture of individual and collaborative activities that together support the collaboration. This characteristic of collaboration was observed in the study reported in Chapter 7 and is implemented in the framework by identifying activities as either belonging to the individual or the group.

Chapter 4 draws from the findings in the jigsaw study to take forward two issues. The first of these is how group characteristics in general are developed from individual ones; the second, and more specific question, raised by the jigsaw study was how individuals were left with different knowledge about both the task and the collaboration following the break up of the group. It appeared from this finding that the relationship between individual knowledge and group knowledge was important in determining a framework to represent collaboration.

In Chapter 4 it was reasoned that Stahl's (2006) view of knowledge as a particular type of artefact was a useful way of describing how individual knowledge is manipulated and both its boundary and content negotiated before it becomes group knowledge. Therefore, any collaboration is based upon a mixture of individual and group knowledge. Knowledge artefacts are recorded as a resource in concrete collaborative schemata, in order to allow an observer to record them in a semi-formal manner.

The second problem considered in Chapter 4 is to try and establish what exactly task complexity is. There are two reasons relevant to this thesis why task complexity needed to be better understood. The first reason, specific to the studies described in the thesis, is to understand how well and understanding of 'simple' tasks can be used to inform a better understanding of 'complex' tasks. The thesis presents two studies that would generally be considered relatively simple and two that would generally be considered relatively complex. The second reason for unpacking what is understood by task complexity is to find a way of representing it in the collaborative framework.

The design decision taken in carrying forward a representation of task complexity into the framework was to use any instance of the concrete collaborative schemata as a representation of the relative complexity of that instance of the task as performed by that specific team. Other representations, for example a numerical rating of complexity or relative linear position between 'simple' and 'complex' were compelling because they offered a simple comparison to say that Task X is simpler than Task Y. However, there did not appear to be any such linear model of complexity that could be drawn from the literature or the studies – the most complex parts of a very simple task can easily be more complex than the very simple parts of a complex task.

Chapter 5 focuses upon how the development of knowledge pushes a problem-solving group through the break down and development of a solution for a complex task. The taskwork model reinforces the design decision of not explicitly stating task complexity as a factor of a concrete collaborative instance; it shows that during a collaboration, the complexity of parts of the task is broken down to a point where activities are well defined and manageable.

The analysis of the Flora and Fauna study in Chapter 5 identifies a set of higher-level activities for problem-solving tasks and the transitions between them. These activities form the basis of the activity types section of the collaborative schemata framework, providing the basic definitions for understanding, bounding, structuring, developing, distributing and completing the task. This provided a clear way of expressing the different task-related activities, but the study did not express teamwork needs.

Therefore, in *Chapter 6*, collaborative teamwork is considered, and from earlier works on flow in individuals (Csikszentmihalyi, 1996) and creative groups (Sawyer, 2003) the idea of *collaborative flow* is presented as a way of expressing the state in which highly efficient collaborative instances attain. In terms of the framework, the idea of a group being in or out of collaborative flow showed that an equivalent set of teamwork activities must exist alongside those that are focussed on taskwork. Their existence, and relationship to the taskwork activities, was investigated in the card sort study in Chapter 7.

Chapter 7 brings together the threads of teamwork and taskwork back to a relatively simple task – groups of four, sorting cards into a pre-defined order supplied on a poster. Analysis of the study contributes further understanding of what is needed to develop teamwork, what is needed to develop taskwork, and the interaction effect between the two. It extends the requirements for the framework by showing that in achieving an overall collaborative goal, collaborating group members perform a mixture of collaborative and individual activities.

Additionally, the study reported in Chapter 7 shows that there are learning effects that are associated with either repeatedly attempting the same task or repeatedly working with the same group of people. The strongest effect is seen when both of these are combined, but there is evidence also that isolated prior experience of either the task or the team has some effect in improving the collaborative flow. Therefore, there is a further requirement for these to be recorded in any representation of a collaborative instance.

8.2 The Collaborative Schemata Framework

The previous chapters of this thesis have built up an understanding of the different strands of collaborative activity, showing that depending on the focus chosen, different elements of collaboration can appear to be the driving force within a group's activity. Drawing together these different elements of collaboration is useful because it provides a structured way of capturing these disparate collaborative threads into a single view of a collaborative process.

8.2.1 Concrete Collaborative Schemata

The design of the schemata framework, drawn from the elements identified in this thesis, is split into two parts. The first is a part that captures elements of individual collaborative instances, which will be called a *concrete collaborative schema*. Within this, an instance of the schema has three main components: first, there is a set of basic collaborative parameters that allow different instances of *concrete schemata* to be situated in relation to each other; second, there is a set of collaborative resources that can be identified at the start of a collaboration; and third, there is a set of types of activity that occur during the collaboration. The elements that form the schemata are illustrated in figure 8.2 to show their development from the prior theory.

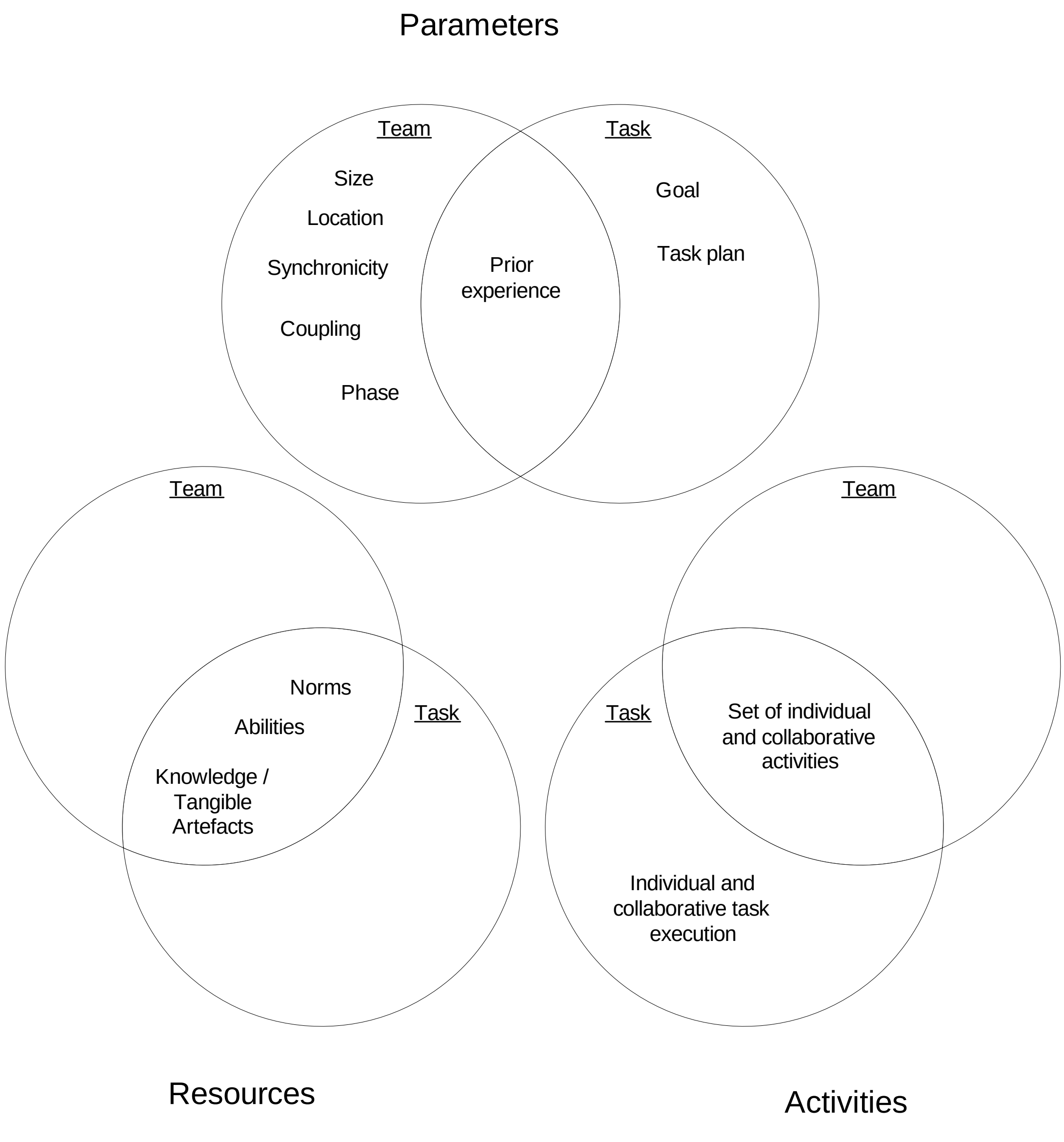

Figure 8.2. Instantiation of Theory in the Collaborative Schemata

8.2.2 Collaborative Parameters

Each of the collaborative parameters has a fixed number of alternatives, so that they can be used to situate any collaborative instance within the multi-dimensional problem space that represents all possible collaborations. The set of options for each parameter has been drawn from either studies or extant literature described in this thesis.

Goal. {fixed, partially negotiable, negotiable}

In the literature, goal and task are terms that can often be used interchangeably; however, it was established in Chapter 2 that for problem-solving groups the goal is an expression of a point that the group would like to reach, without – to a greater or lesser degree – a clear understanding of how to get there. The goal is an important component in collaborative work, because the level to which it is fixed shapes the collaboration.

For example, in the jigsaw study there was a goal that was *fixed* – the group members understood that they needed to replicate the picture on the box lid by combining the jigsaw pieces inside the box.

By comparison, in the flora and fauna study, the groups both had initial ideas about their goal, but this had to be honed by breaking the task down, attempting parts of it, and using newly-developed knowledge to redefine both the goal and their understanding of the goal. Nevertheless, each group in the study had a specific brief to produce a particular type of poster, so although they had some degree of freedom their goal was only *partially negotiable*.

A *negotiable* goal would apply to things like 'blue sky' design meetings, where perhaps in the first session there would be no prior-stated restrictions on defining what the group's goal will be. Although it is beyond the scope of this thesis, it seems unlikely that a fully negotiable goal will exist in any group situation for long, before constraints are defined, negotiated and accepted.

Task plan. {known, partially known, unknown}

As the thesis has previously stated, the group's task differs from its goal in that the task is a statement, or understanding, of the activities required to complete the goal, how they relate to each other and who will complete them.

Even when the task is relatively simple and the goal is clearly defined, static and well understood, it is likely that a group will not fully understand its task at the outset. It was observed in the card sort study that this is a combination of having to understand what is possible in a task and what works, how to work with the other people in a group for any given instance, as well as having to change strategies when people become more adept. The groups that repeatedly sorted cards began with an iteration where the task plan was *unknown*, developed this in a further few iterations where the task plan was *partially known*, before settling on a particular way of completing the repeated task with a plan that was *known* from the outset.

Number. {3..n}

It is suggested that the minimum number of people assumed to be a group is three, in line with the Fjermestad and Hiltz (1999) review discussed in Chapter 2. Fewer than this (i.e. a single person or dyad) and the interactions are generally perceived to be substantially different. The upper limit has been left open, but again the literature suggests that group sizes of around eight and larger behave differently to those in the range of three to seven. Studies in this thesis focussed upon groups with either three or four members.

The number of people in the group not only affects how they collaborate, but also impacts upon a number of other factors. As has been discussed in Chapter 2, there has been much discussion in the literature about what constitutes the optimum number of people for a task. The purpose of including this amongst the team-related components is so that it is possible to judge in a systematic way what the appropriate number of people is for any given collaboration. This is important when considering the issue of technological support, because if the number of people in a group significantly alters the way in which they work, then any technological intervention should be based on the most effective group size.

Location. {co-located, predictably distributed, unpredictably distributed}

By this, the thesis refers to whether the group members are co-located or distributed. This thesis has focussed on studies that are predominantly *co-located* – although the flora and fauna study had points at which the participants worked alone, or in pairs, in different locales. The distinction between *predictably* and *unpredicatably distributed* was made by Grudin (1994b) in his classification of groupware and is included here as an appropriate categorisation based upon that, but it is beyond the scope of this thesis to explore that distinction in detail.

It can be imagined, however, and this is supported by many group studies (Fjermestad and Hiltz, 2001), that working in the same location or in different ones creates a very different collaborative experience, even if other factors are the same. For example, Chidambaram (1996), in a study of repeated meetings of distributed groups, found that their distributed groups took longer to develop relational intimacy compared to face-to-face groups.

Synchronicity. {synchronous, predictably asynchronous, unpredictably asynchronous}

This parameter describes whether the group members are interacting synchronously or asynchronously; also associated with this is Grudin's (1994b) distinction of whether the asynchronicity is predictable or not (see Chapter 2).

In this thesis, the studies have typically represented synchronous interactions, as in the jigsaw and card sorting studies, as well as in the co-located meetings of the flora and fauna study; however, the groups in the flora and fauna study also scheduled unpredictably asynchronous work to allow data gathering between meetings (defined as unpredictable, rather than predictable, because although rough briefs were scheduled for individual group members, the particular times that they undertook these individual activities were left to themselves).

Coupling. {strong, loose, mixed}

Coupling describes how strongly dependent the activities of different people are upon each other, which in turn determines whether they need to coordinate, cooperate or collaborate. In the studies presented in this thesis, the tasks have required the groups to predominantly perform strongly coupled activities, which has resulted in activities that are collaborative or cooperative. The thesis proposed in Chapter 2 (p37) that loose coupling of activity interaction would require activities that would be better described as either coordination, or perhaps even just a shared awareness.

Phase. {forming, storming, norming, performing, adjourning}

As discussed in Chapter 2 and demonstrated in the studies throughout the thesis, Tuckman's group phases provide a rough categorisation of where a group is in its development. By considering the group's development phase, more sense can be made of their behaviour, in particular their collaborative flow. There is often a transition phase where observed groups appear to be between two states, so it would also be reasonable to record observed meetings as being in a forming/storming, storming/norming, etc. phase.

Task experience. {0..n}

This parameter is drawn from the analysis of the card sort study in Chapter 7, where analysis of the repeated measures showed that both repeatedly completing the same task and repeatedly working with the same team had an effect on developing collaborative flow and therefore improving the efficiency of the collaboration.

The likelihood of the group having comparable prior task experience will be much greater in simple tasks than in complex ones, although this depends upon the level at which the observer chooses to situate the task. For example, the group members may have the goal of collaboratively writing a software module and they may each have previously written other modules. The development of each software module is a complex, and probably unique, task, but it may be judged to be experientially similar enough for the purposes of capturing the collaboration.

Team experience. {0..n}

This parameter is also drawn from the analysis of the card sort study in Chapter 7. This is a measure of the number of tasks that the same group composition has previously worked on. The measure assumes that all members of the team remain the same.

Like prior task experience, this parameter becomes harder to judge in complex tasks. These difficulties are explored further in Chapter 9.

8.2.3 Collaborative Resources

The resources section of the collaborative schema framework is semi-formal, unlike the rigid selection of parameters for the first section. In this section, the observer of a collaborative instance is able to capture as much information as they can about the artefacts held by the group, the norms that guide their behaviour and the abilities that either the group or its individual members possess.

Knowledge artefacts.

In Chapter 4 the way in which a group builds shared knowledge that they can apply to their task was explored. By contrast, when considering task knowledge as a component of collaboration, the focus is on the knowledge that the group has available to it at the start of the collaboration. It is by analysing this starting point, that partial clues as to how competent the group is to undertake the collaboration can be derived. In a relatively simple, repeated task – such as that in the card sort study – it is easier to see the task knowledge that shapes how a group collaboration evolves. Obviously for complex tasks this is more speculative, but in any collaboration the identification of 'common ground' at the start gives the group its known knowledge resources for that collaboration.

Tangible artefacts.

By understanding the resources available to a group, the distinctions between its abilities and its capabilities can be made. In simple tasks, such as were observed in the jigsaw study, these resources may be directly related to the task and quite obviously appropriate – e.g., the jigsaw pieces and the box. However, when combined with other factors, it maybe that a resource that is appropriate in one instance is not so in another. For example, it could be reasoned that if ten people had tried to collaborate on the jigsaw, then the resources used by the original three participants would perhaps be insufficient – they may struggle to fit around the table; there would not be enough chairs; they may not all be able to see the picture, or reach the pieces, and so on.

Norms.

Norms adopted by a group are not usually described as a resource, but in the collaborative schemata they provide an extra dimension to understanding the way in which specific collaborative instances unfold. The difficulty with group norms is that they can often be implicit and only apparent to an observer when they are broken and there is censorship from other group members. Although this means that it is far from likely that a full picture of norms can be built from any external observation, any norms that are captured will help to explain some of the patterns of activity that are observed.

Abilities.

Each group member brings certain abilities to a collaborative activity, but at the same time collaborative abilities are very much a group-emergent characteristic. Combinations of different individuals' abilities can lead to new abilities that could only be possible when combining more than one person. This combination of abilities needs to be further combined with other factors for group-emergent capabilities to be observed. The abilities that can be captured at the start of a collaborative activity are limited – it is possible to ask the group's members to list these abilities, but in pursuing complex tasks the needs of the task are often not understood in advance and therefore many of the abilities that might address these needs cannot be captured until this point.

The study of self- and collective efficacy in Chapter 3 showed how agency is brought about by a certain level of confidence in an ability (either at an individual or group level), so the abilities captured by an external observer are likely to be only those demonstrated actively as capabilities; other abilities may remain hidden, particularly at an individual level if the individual does not have the requisite level of self-efficacy to action an ability.

8.2.4 Collaborative Activities

The final category that has been considered in building a picture of collaboration is that of types of activity. Here the thesis introduces a candidate list of activity types that could be specific to a particular collaboration, but could also be abstracted as a general characteristic. By considering both of these issues, the thesis bridges the gap between specificity that accurately represents an individual collaboration and generalisability that will enable the identification and development of support mechanisms for particular aggregations of collaborative activity.

The prototypical set of activity types presented here has been drawn from the taskwork model and the conceptual analysis of flow. First, each of the states from the taskwork model and it is reasoned what the associated activities for these states represent. Added to this are the further activities of *negotiation* and *monitoring* which were seen to be important when considering how groups repair *disruptions in collaborative flow*. The final activity of *execution* is an important addition, as all the other activity types describe how a group prepares for attempting activities, but a group *in collaborative flow* also needs to be able to make those attempts.

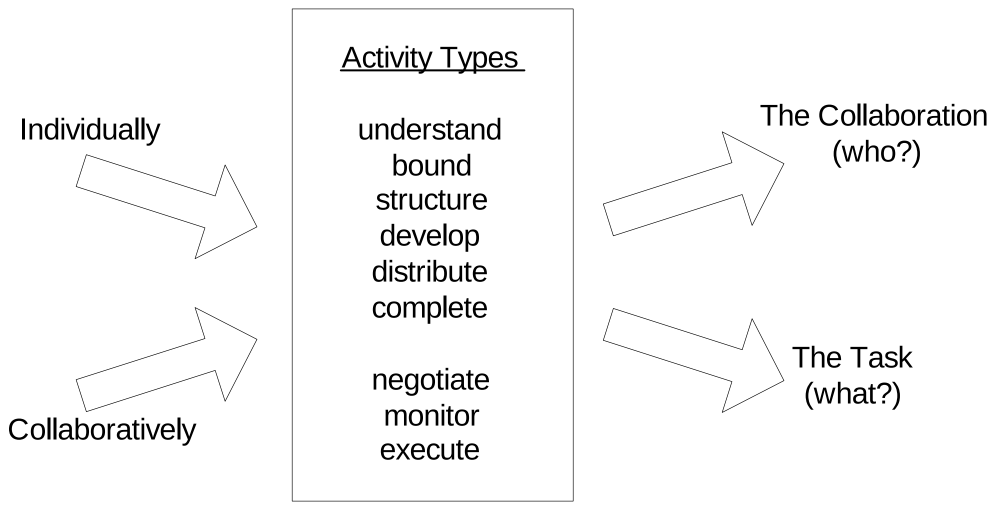

Figure 8.3. Permutations for activities within the collaborative schemata

Each of these candidate activity types is considered in turn to see how it relates to taskwork and teamwork, and whether it is an appropriate descriptor for types of activities that support both. Also, the study of collaborative flow showed that during a collaboration, group members choose between individual activities and collaborative activities; the following activity types are also considered to see if they are appropriate to make this distinction.

Understand.

Any collaboration is built around shared understanding, and without it the groups cannot develop the periods of collaborative flow necessary to complete their tasks. So, this category represents the mechanisms a collaborating group is using for its shared understanding. Is the understanding explicitly stated, implicit or does it need to be negotiated? In the taskwork model, the emphasis was on instances where the groups had to *understand the task*. Most of the instances from the flora and fauna study group meetings can be best described as points where the group members *collaboratively understand the task*, i.e., they are entering a shared process where they collectively work to change their shared understanding to more accurately match their goal.

Any point at which a group member decides to try to *individually understand the task* instead may lead to a future disruption in flow, where that person's new understanding needs to be resolved against that of the other group members.

The comparable activities of trying to *individually* or *collaboratively understand the team* were also observed in both the flora and fauna and jigsaw studies. Group members trying to understand each other's behaviour is the process that leads to the development of group norms and allows the group to progress through Tuckman's development phases.

Bound.

In the taskwork model, *bounding the task* was identified as a phase of task breakdown where the group re-appraised what they had identified as the scope of the work required in order to achieve their goal. Again, the observations in the flora and fauna study were of the group trying to *collaboratively bound the task*. Observing group members *individually bound the task* is more difficult, because they may do this implicitly. However, situations where individuals withdraw from a collective discussion before encouraging the group to change their task boundary could be examples of this.

The act of *bounding the team*, rather than the task, also provides a good descriptor for the process of development of the group relationship; the boundary in the case of the team would be their shared norms of behaviour. The act of *individually bounding the team* requires an individual authority (such as a pre-defined group leader) that was not present in the studies for this thesis, but *collaboratively bounding the team* was a regular activity of norm development and acceptance.

Structure.

Each of the studies at times involved group members trying to structure their activities throughout the different collaborations. Doing so is a key part of the taskwork model presented in Chapter 5. Giving structure to known activities allows the group to actively attempt parts of complex tasks while they work at trying to understand other parts of it. As the thesis has shown in the taskwork model, structuring activities involves determining what resources are required (including human resources) and how the activities are dependent upon each other. During the flora and fauna study's group meetings, the group members had to *collaboratively structure the task*, so that they could use that structure to distribute activities to be completed later. Situations where someone might *individually structure the task* would include those where someone within the group has been designated that role (e.g. Orre and Middup, 2006), or situations where the group members are working asynchronously and therefore have to make individual choices. Situations where group members *individually structure the task* could lead to disruptions in collaborative flow, where the order of these activities becomes important to other group members at a later time.

The act of *collaboratively structuring the team* is a description of the process of collectively identifying roles that group members will take within their group. These could be formal roles, such as being the group leader, or something short-term that is appropriate for identified task activities. For example, in the jigsaw study, a group was structured so that one person took responsibility for the edges, whilst the others worked on different parts of the centre of the jigsaw. Once a leader is established, either through an external directive or as a result of previous *collaborative structuring*, there may be instances of that leader *individually structuring the team* by directing other group members to take particular roles. As was observed in the flora and fauna study, when there is no official leader, this role may move between different group members when different task requirements make one person more suitable to lead than another.

Develop.

Aside from identifying activities, groups need to have processes for developing these activities – particularly in complex tasks, where the initial purpose may not be fully understood – until they are fit for purpose. This is another activity type that was identified in Chapter 5 as a key state in breaking down complex tasks into manageable activities.

Here it is proposed that the development of the task is an activity itself that can be pursued either collectively or individually. In the taskwork model, this process is a result of earlier structuring of the task – or an understood part of it – which highlights a gap in the activities that have been identified to complete the task. The flora and fauna study showed examples of those group members when they *collaboratively develop the task*. As with the other activity types, the point where group members *individually develop the task* can be seen as something done outside the group meetings and the differences from these actions are resolved as disruptions in flow. It is also possible that given a different group structure –

i.e. a particular combination of roles – then this could occur individually within a co-located meeting.

In the same way that the *development* activity type supports and extends the *structuring* activity type for *task*-related activities, it can also do so for *team*-related activities. Group roles can often be more dynamic than activities, because once created they can persist over a long period of time. Once a group has been structured with certain roles, the group members can more easily see the gaps between the defined roles and the extant needs of both task and team. From this point they can either *individually* or *collaboratively develop the team* in order to make the roles fit their current needs.

Distribute.

Any group of collaborators must have a method of distributing their activities. The method in which they do this may be forced upon them in some instances (for example, in a commercial enterprise, the organisational hierarchy may determine how activities are distributed); in other situations the group members themselves must develop a method for distributing activities. In Chapter 5, the thesis identified the distribution of activities as one of the key states of the taskwork model and, as such, this is an activity type that a collaborating group must demonstrate in some form if they complete, or significantly progress, their task.

The act of *collaboratively distributing the task* is one where the group members work on a shared activity of splitting the activities that they have structured into packages of work for individuals, sub-groups or the whole group. Similarly *individually distributing the task* would be when someone in the group has a particular remit to tell the others which activities to perform.

Similarly, the process of *individually* or *collaboratively distributing the team* is an activity type that follows on from structuring the team with appropriate roles. The distribution is the activity of giving or taking those roles identified as the necessary structure for the team.

Complete.

The group members must possess or develop mechanisms for identifying that activities are complete. This means that the notion of an activity being complete must be agreed at group level; otherwise this is another potential area for disruptions in the flow of collaboration. In the taskwork model, the completion of sub-tasks is seen as a series of stages to completing the main group task and situations where the group is unable to agree completion of certain activities can lead the group members to reconsider what the task boundary is.

To *collaboratively complete (part of) the task* the group must agree that an activity has achieved its planned outcome and that outcome is still relevant to the overall completion of the task. The same activity can happen at an individual level, but any individually completed task-related activities that have an output that feeds back into the collaboration must then also have that completion validated by the group.

The idea of *individually* or *collaboratively completing the team* fits well with the final group phase of *adjourning* (Tuckman and Jensen, 1977). This could happen individually if someone left a group that continued to collaborate on the same task without them. Otherwise, when the group completes or ceases to continue with its main task, then there may be an explicit activity of *collaboratively completing the team*.

Negotiate.

This activity type represents the negotiation that takes place with a group, as the thesis described in Chapters 4 and 5. Negotiation is an important characteristic of the resolution of disruptions in flow; it is also an important process in the adoption of group artefacts – both tangible artefacts and knowledge artefacts are adopted into the group through a negotiation process.

Unlike the other activity types in this set, the activity of *negotiation* has no individual aspect to it. There are types of negotiation that are not collaborative – referring back to the 'C's model in Chapter 2, it is reasonable to assume that people may negotiate in a variety of ways that does not involve a shared goal. Some of these – for example *competitive negotiation* – could be described here as *individually negotiating the task* or *team*, but this does not fit well with the purpose of the activity types, which is to describe individual and collaborative activities that a performed in order to achieve a shared goal.

The activity of *collaboratively negotiating* applies equally well to either *the task* or *the team*. Any point at which something is proposed by a group member and not universally accepted by the other group members without modification requires a negotiation activity.

Monitor.

The way that group members monitor each other's progress is also important in a collaborative activity. It is important for two reasons: first, it defines how the group is led – either by an established leader, or peer led; second, it determines how well the collaboration will flow – i.e. if group members do not monitor each others work, or if they misinterpret what they observe, then there will be disruptions in the flow.

There was some evidence of *collaborative monitoring* in the studies. For example, in some of the card sort tasks the whole group would *collaboratively monitor the task* after all the cards had been laid on the table. However, it was far more common for *monitoring* to be an *individual* activity, the result of which was fed back into the group; this would cause a disruption in flow that the group would then need to resolve. It is possible that an individual could *monitor* some aspect of *task* or *team* that would not lead to a disruption, but generally any individual monitoring that resulted in no observed problem was difficult to identify.

Execute.

Many of the types of activity described here relate to the cognitive issues involved in breaking down a complex task into manageable activities and in working together as a group. However, it is important to acknowledge that none of this has value unless the group members have the capability to execute the actions that they identify. In the fully co-located studies that were observed, the connection between activity identification and execution was very short, appropriately for those tasks; in the flora and fauna study a longer loop pattern, where an activity was identified in one group meeting, executed by a group member later and elsewhere, and then reported upon at the next gathering was often observed.

8.2.5 Abstract Collaborative Schemata

The second part of the collaborative schema framework is a set of *abstract collaborative schemata*. An abstract schema has the same form as a concrete schema, but rather than representing an observed collaborative instance it represents a designer's view of the requirements for a particular type of collaboration. This means that they will need to draw together a number of concrete collaborative schemata that cover the range of types of collaboration that they wish to support. This range may be guided by certain ranges of parameters, certain patterns of activity, or simply be the set of collaborative instances that they have observed in a particular setting.

Therefore, an abstract collaborative schema has a similar look to it as a concrete collaborative schema, but it represents a *potential* collaborative instance developed by the designer. In terms of representation, the parameters may be expressed in ranges, the resources will be a composite requirement for artefacts, norms and abilities and the activities will be split into those that are considered *core* (i.e. those that must be present) and those that are considered *auxiliary* (i.e. those that may be beneficial in the collaboration).

8.3 A Worked Example

This section takes three representative instances from the card sort study, the first, second and twelfth attempts by Group 1, and shows how these can be represented as concrete collaborative schemata. The reason that these are representative is because the analysis in Chapter 7 showed that there were radically different task performances in these three trials. After the concrete schemata have been developed, abstractions are made to show how following this process helps to build an understanding of these differences.

Group 1 Task 1

The first part of the concrete schema – the parameters – can be identified from the description of the task in Chapter 7. The goal is *fixed*, as the group is instructed to produce a particular output; however, the task plan to achieve that goal is *unknown*, as this group has no prior experience of either the task or working with each other to draw upon (this also means that both their task and team experience must be *0*, and they will begin working in the *forming* phase of group development). The other parameters are the number of group members, *4* and how they are located (they are *co-located*); they are also working *synchronously* and the coupling of their activities is *strong*.

At the start of the task, because it is a new group of people being observed and a new task, determining their resources, other than tangible artefacts, is difficult. It can be tentatively assumed from the group members' behaviour that they began the activity with some prior familiarity of playing cards. The group may have some implicit shared norms, but as they haven't worked together before these won't even be apparent to them at this stage, let alone an external observer.

Building a picture of the collaboration from the descriptions of observations of this task in Chapter 7, the following sequence of activities was identified:

Individually/Collaboratively understand the task. The task begins with a member of the group reading the instructions for the task. Their initial individual understanding of the task is transformed into a shared understanding as the other group members observe one person trying to sort the cards.

Individually structure the task. The person that tried to sort the cards suggests that they just lay the cards according to the poster pattern (although his actions show that he means to sort the cards into the eight columns, before laying the cards out). There are no alternative suggestions, so he begins and the others follow.

Collaboratively execute the task. Everyone takes a few cards and begins to sort them.

Collaboratively understand/negotiate the task. Before they have finished sorting the cards, the group members realise that they need to decide whether to lay the cards lengthwise or breadthwise on the table; they negotiate a group decision and continue sorting the cards.

Collaboratively bound the team. There is an interlude where the group members share a joke about the number of tasks that they have to do (they know that they have 13 tasks to complete, although they don't yet know what they are). This helps to build the interpersonal relationships between the group's members.

Collaboratively understand the task. The next part of the task progression is where someone suggests that they check the order of the cards, which leads to the group members discussing the needs of the task again.

Collaboratively execute the task and *individually monitor the task.* They continue to lay cards on the table, but during this one of the group members corrects another when they lay two cards that are touching each other. This shows that in this task the monitoring process can be interspersed with task execution.

Individually structure the team. The same person that was monitoring the progress of another team-mate in the previous activity now suggests that the two of them start work on the other side of the table.

Collaboratively monitor the task/team. As the group members continue to lay cards, they now explain to each other what they are doing, enabling the monitoring process to develop into a collaborative activity.

Collaboratively develop the team. As part of this monitoring process they notice that the cards are split into two packs with differently-coloured backs, so they organise themselves into two pairs to work one pack on either side of the table.

Collaboratively complete the task. Once they have laid nearly all the cards, they check what they have done against the instructions. They discuss whether they have met the criteria of the instructions and, once satisfied that they have, one person rings the bell.

Table 8.1. Concrete Collaborative Schema for Card Sort Group 1 Task 1

CONCRETE COLLABORATIVE SCHEMA			
description			
This is the first attempt at a card sort by Group 1.			
parameters			
task		team	
Goal:	fixed	Number:	4
Task plan:	unknown	Location:	co-located
Task experience:	0	Synchronicity:	synchronous
		Coupling:	strong
		Phase:	forming
		Team experience:	0
resources			
Knowledge artefacts:	Prior knowledge of playing cards		
Tangible artefacts:	Two packs of cards, poster, pins, Blutack, table, chairs		
Norms:	Unknown		
Abilities:	Unknown		
activities			
Individually understand the task			
Collaboratively understand the task (observed 3 times)			
Individually structure the task			
Collaboratively execute the task			
Collaboratively negotiate the task			
Collaboratively bound the team			
Collaboratively execute the task			
Individually monitor the task			
Individually structure the team			
Collaboratively monitor the task			
Collaboratively monitor the team			
Collaboratively complete the task			

Group 1 Task 2

Some of the parameters remain the same as the first iteration: the goal is *fixed*, the number of group members is still *4*, they are *co-located*, working *synchronously* and the coupling of their activities is *strong*. Their task and team experience are both recorded as *1*, as they have now all completed the same task once and all worked together once. Unlike the first time that they attempted the task, they now have some idea about the nature and order of the sub-tasks required to sort the cards; therefore, the task plan is *partially known*. The group's development phase is also starting to show some signs of storming, with group members challenging each other over both decisions and actions; as this is only apparent some of the time, the phase is recorded as *forming/storming*.

The resources have also changed between iterations; the group members now have demonstrated the ability to sort and to lay cards and they have formed shared knowledge artefacts on *how* to apply these two abilities (some or all the group members may have already had these abilities, but this could not be observed, whereas the shared knowledge could not have existed because they had not worked together prior to the first iteration of the task). There are no obvious changes to either developed norms or the tangible artefacts available.

Building a picture of the collaboration from the descriptions of observations of this task in Chapter 7, the following sequence of activities was identified:

Individually execute the task and *individually structure the team*. In this second attempt, even before they read the instructions, the group members begin by organising the artefacts to where they were at the end of the previous task. As well as task execution, this shows an element of structuring the team, because they carry these initial roles through the remainder of the trials (although, at this time, they still are not aware of how many of the trials will be a card sort).

Collaboratively understand the task. One of the group members reads the instructions out to himself and the others.

Collaboratively structure/negotiate the task. This time, they discuss very carefully how they are going to complete the task. Different people suggest different things, so the new structure is built through a process of negotiation.

Collaboratively execute the task. The group members split the cards into suits.

Individually distribute the task. Once the cards have been split into suits, one of the group members instructs the others to lay one suit each on the table.

Collaboratively negotiate/distribute the task. This is initially accepted, but then the group begin to discuss how well it will work as a method. They decide it will be suitable, so they then distribute the activities in the same way as originally instructed.

Individually understand the task. One of the group members has to ask which way around the cards are being laid. The others already know and one tells him. This illustrates a way in which small disruptions in flow are managed by the groups in these series of tasks.

Collaboratively develop/negotiate the task. One group member has to move another's cards so that his will fit. This sort of development illustrates how they are gradually learning to work together and how collaborative flow develops through this shared understanding.

Individually develop the team. When a group member gets behind, he asks for help. This begins to develop the roles that they will take in later iterations of the task.

Collaboratively understand the task. Next follows another discussion about where to lay the cards, so that the suits follow the same order as the poster.

Individually execute the task. Near the end, only one group member is left laying cards.

Collaboratively develop the task/team. As the other three group members are free – waiting for the fourth person to finish – they discuss a better strategy for next time.

Collaboratively complete the task. As with the first iteration, they agree that the task is complete and someone rings the bell.

Table 8.2. Concrete Collaborative Schema for Card Sort Group 1 Task 2

CONCRETE COLLABORATIVE SCHEMA			
description			
This is the second attempt at a card sort by Group 1.			
parameters			
task		team	
Goal:	fixed	Number:	4
Task plan:	partially known	Location:	co-located
Task experience:	1	Synchronicity:	synchronous
		Coupling:	strong
		Phase:	forming/storming
		Team experience:	1
resources			
Knowledge artefacts:	Prior knowledge of playing cards, sorting cards, laying cards		
Tangible artefacts:	Two packs of cards, poster, pins, Blutack, table, chairs		
Norms:	Unknown		
Abilities:	Sorting cards, laying cards		
activities			
Individually execute the task (observed 2 times)			
Individually structure the team			
Collaboratively understand the task (2)			
Collaboratively structure the task			
Collaboratively negotiate the task (2)			
Collaboratively execute the task			
Individually distribute the task			
Collaboratively distribute the task			
Individually understand the task			
Collaboratively develop the task (2)			
Individually develop the team			
Collaboratively develop the team			
Collaboratively complete the task			

Group 1 Task 12

The same parameters that were unchanged between the first two iterations remain the same right through to the twelfth and final attempt at card sorting: the goal is *fixed*, the number of group members is still *4*, they are *co-located*, working *synchronously* and the coupling of their activities is *strong*. Their task and team experience are both recorded as *11* to reflect the experience gained from the previous card sorting instances. By the time the group has reached this twelfth turn the task plan is *known* – they settled on their best approach about halfway through the twelve turns and it hasn't varied since. The group's development phase is recorded as *performing* because they are now fully settled on a way of working together.

The resources have changed very little between the second and twelfth iterations. Although the card sorting/laying knowledge artefacts may have been refined and the associated abilities honed or improved, the model does not capture these changes. A possible norm that is worth noting is that for each attempt at the card sort, each person stands in the same place – this is more likely to be an issue if the group membership were to change.

Building a picture of the collaboration from the descriptions of observations of this task in Chapter 7, the following sequence of activities was identified:

Individually execute the task. The group members begin by putting the artefacts in the same places as previous trials, then immediately work through the execution of their task plan.

Collaboratively execute the task. There is one point where a group member tells the others that he is missing a couple of cards; one of his colleagues helps him to find them.

Collaboratively distribute the team/task. Near the end, two of the group have finished, so one offers to help one of those still working.

Individually complete the task. With the group now in good collaborative flow, there is no discussion at the end as to whether they are finished or not. The person nearest the bell decides that they are and rings it.

Table 8.3. Concrete Collaborative Schema for Card Sort Group 1 Task 12

CONCRETE COLLABORATIVE SCHEMA			
description			
This is the twelfth attempt at a card sort by Group 1.			
parameters			
task		team	
Goal:	fixed	Number:	4
Task plan:	known	Location:	co-located
Task experience:	11	Synchronicity:	synchronous
		Coupling:	strong
		Phase:	performing
		Team experience:	11
resources			
Knowledge artefacts:	Prior knowledge of playing cards, sorting cards, laying cards		
Tangible artefacts:	Two packs of cards, poster, pins, Blutack, table, chairs		
Norms:	Positions around the table		
Abilities:	Sorting cards, laying cards		
activities			
Individually execute the task			
Collaboratively execute the task			
Collaboratively distribute the team			
Collaboratively distribute the task			
Individually complete the task			

Abstract Card Sort Schema

With three observed instances of the card sort, it is now possible to attempt to define an abstract collaborative schema for sorting cards. A suggested abstract schema based on the observations is shown in table 8.4. The suggested schema is only one possible representation that could be drawn from the previous concrete collaborative schemata and the decisions made to achieve this representation, and the alternatives, are considered here.

The first design decision to be made is over what range to situate the collaborative parameters. In this example, the decision has been made to situate the abstract collaboration somewhere in the middle of the development observed through the three concrete schemata. This is a general strategy that could be employed in building abstract schemata when group development has been observed and the objective of the abstract schema is to represent a general view of those concrete collaborative instances.

Alternative approaches could be taken that would shape the purpose of the representation differently. For example, it could be considered that the collaborative behaviour over the three instances is too broad and represents different things – in the first, and to an extent the second, instance there is a primary focus on working out what needs to be done; whereas, in the final instance the focus is upon delivery and collaborative flow. These could be separated into two abstract schemata to try to capture the different collaborative focuses.

Similarly for the collaborative resources, a middle ground has been selected from the available concrete schemata. An assumption has been made that in the abstract representation, a group of collaborators would have knowledge and ability pertaining to the laying and sorting of cards. A further assumption has been made that the repeated behaviour of participants standing in the same place is not relevant. However, both these design decisions are judgmental and further concrete collaborative instances could affect how these are made.

The process of separating out the *core* activities for the abstract schema from the *auxiliary* activities was difficult because of the great differences between the group's first attempt at the card sort compared to their final attempt. The approach taken, given there were three concrete schemata to work with, was to consider activity types that were observed in any two of the instances to be potentially core to this type of collaboration. Again, further observed concrete instances could hone this choice, or this could be considered another reason to split the abstraction into two schemata that represent the earlier and later collaborations in the sequence.

Table 8.4. Abstract Collaborative Schema for Card Sort

<table>
<tr><th colspan="2">ABSTRACT COLLABORATIVE SCHEMA</th></tr>
<tr><th colspan="2">description</th></tr>
<tr><td colspan="2">This is the abstracted model of collaboration for sorting cards, based on concrete collaborative schemata of instances of groups of four sorting cards.</td></tr>
<tr><th colspan="2">parameters</th></tr>
<tr><th>task</th><th>team</th></tr>
<tr><td>Goal: partially fixed
Task plan: partially known
Task experience: 0..11</td><td>Number: 4
Location: co-located
Synchronicity: synchronous
Coupling: strong
Phase: storming/norming
Team experience: 0..11</td></tr>
<tr><th colspan="2">resources</th></tr>
<tr><td colspan="2">Knowledge artefacts: Prior knowledge of playing cards, sorting cards, laying cards
Tangible artefacts: Two packs of cards, poster, pins, Blutack, table, chairs
Norms: Unknown
Abilities: Sorting cards, laying cards</td></tr>
<tr><th>core activities</th><th>auxiliary activities</th></tr>
<tr><td>Individually understand the task
Collaboratively understand the task
Collaboratively execute the task
Collaboratively negotiate the task
Individually structure the team
Collaboratively complete the task
Individually execute the task
Collaboratively distribute the task</td><td>Individually structure the task
Collaboratively bound the team
Individually monitor the task
Collaboratively monitor the task
Collaboratively monitor the team
Collaboratively structure the task
Individually distribute the task
Collaboratively develop the task
Individually develop the team
Collaboratively develop the team
Collaboratively distribute the team
Individually complete the task</td></tr>
</table>

8.4 The GSS Designer and the Framework

The purpose of the development of the collaborative schemata framework through this thesis is aimed at supporting the analysis and design of GSS for problem-solving groups. The concrete schemata represent instances of collaboration in a multi-dimensional problem space; the abstract schemata represent useful collections within that space. Concrete schemata can be created by observing instances of collaboration and abstractions drawn from collections of those schemata.

Preece et al. (2002) suggest that there are two distinct types of evaluation, *formative* and *summative*. Formative evaluations take place during the design process to ensure that the design meets the needs of the users, whereas summative evaluations are used to assess the finished product. Each of these methods can make use of the collaborative schemata framework to the benefit of the GSS designer; they are considered in turn here.

Summative evaluations

GSS designers can benefit from using the collaborative schemata framework for the summative evaluation of existing systems by using it as a means of building up a comprehensive picture of the type of GSS that they wish to support or improve. Each individual concrete collaborative schema gives a semi-formal description of how a collaboration progressed through its activities, from its starting point represented by the parameters and resources. However, what it does not do is capture either the effectiveness or the efficiency of the collaboration in terms that are directly comparable to other collaborations.

Although the effectiveness and efficiency of the collaboration are not directly captured, the GSS designer can derive this by two means. One way is to use direct experience of specific collaborations to select those that achieved things the designer wishes to perpetuate or improve as exemplar concrete instances. From these, the designer can abstract common elements of the concrete examples in order to create a list of elements that they wish support in their design. These elements may be particular parameters, resources or activities. If the GSS designer does not have direct experience of a concrete collaborative instance, then they might compare its profile of activities to those that they do have direct experience of in order to make a judgment on its effectiveness and/or efficiency.

Formative evaluations

The GSS designer can also make use of the collaborative schemata framework in formative evaluations by building concrete collaborative schemata to represent user trials at various phases of development. Using these, the GSS designer can identify abstractions to determine if the development is delivering the types of collaboration identified in the design process.

8.5 Conclusion

The collaborative schemata framework has been developed from a number of sources, some of which were tested empirically in this thesis and others drawn from established literature. The next stage is to begin to validate the framework as a single entity and to test its utility.

In this chapter, worked examples using the card sort study from Chapter 7 were used to illustrate how the framework can be applied. However, for GSS designers the collaborative instances that are supported by GSS are likely to be much more complex. Therefore, a more complex task is used next to provide a lightweight validation of the framework; this validation will then lead to reflections on how the framework can be improved, both in terms of representation and in terms of application.

9 Lightweight Validation of the Framework

> Group success tends to be attributed to the skill and effort of the members. Opposing teams or other external features are likely to be blamed for failure.
>
> Paul Hare (1992, p35)

The previous chapter introduced the idea of collaborative schemata as a framework that can be used to express the structure of specific collaborative instances, but also can be used to develop abstractions that span different collaborations, thus giving insights into areas where support interventions could be considered. Also, it applied the framework to simple tasks (instances from the card sort study) to demonstrate how it can be practically applied.

This chapter reports a more thorough test of the collaborative schemata framework with a lightweight validation of the framework's theoretical contribution when applied to a complex task. There are two outputs to be drawn from this exercise: the first is to test more rigorously the framework's ability to represent all the elements of collaboration identified in the thesis; the second is to consider how the framework's method of use needs to be developed to support GSS designers.

The study chosen for this validation is representative of the type of work group study already considered in this thesis. It is an appropriate study for the lightweight validation of the framework because of its similarity in structure to the *flora and fauna study* introduced in Chapter 5.

9.1 PDA Study

This section introduces a new study, identified in this thesis as the *PDA Study* because of a device offered to each of its participants for the duration of their participation, which provides a different complex task for analysis.

The pattern of group work that the design of the study was intended to provide, was of strongly-coupled groups that meet reasonably frequently to report their individual progress on a task, to collate this to a shared understanding of the group's overall progress towards a task, and to schedule further individual activities that the group considers to be most important for the next phase of taskwork. This pattern of work is closely related to observed fieldwork (Orre and Middup, 2006) and therefore is representative of patterns of behaviour outside the laboratory in which it is set.

Two groups of four people were asked to participate in a three-week exercise to create a promotional video to encourage environmental awareness on campus. The tag for their brief was 'Reduce! Reuse! Recycle!'. The groups were independent of each other and did not work concurrently. The groups were encouraged to have as many co-located meetings that they felt were required to complete the task effectively within the three-week period.

The participants were asked to let the researchers know of group meetings in advance, and for the meetings take place in the University of Bath HCI Laboratory, so that they could be recorded. Aspects of the groups' sessions are shown in figures 9.1 and 9.2.

Figure 9.1. Group 1 observing and discussing possible uses for video clips

This task and group combination is a reasonable approximation of a large number of work-based task-oriented groups. Some are more widely geographically dispersed between co-located meetings than others, but the nature and purpose of the co-located meetings themselves are broadly similar. Using the Poole et al. (2004) classification (described in Chapter 2), this study is based on the functional and temporal perspectives.

Immediately prior to each group's first co-located meeting, the task was explained to them and they were given a brief run-through of the different artefacts provided for them to create the video. They were also told that they could introduce new artefacts into the group if they believed that these were more useful to them than the ones provided.

Each group member was provided with a loaned Hewlett Packard iPAQ hp6915 for the duration of the study. This also included a pay-as-you-go mobile SIM card with some free credit. The purpose of providing these devices was that group members would have a means of capturing ideas to bring to the co-located meetings, as well as an effective mode of communication between meetings. However, as with all other artefacts provided, it was made clear to the group members that they could use other artefacts to meet these needs if they preferred to do so.

Figure 9.2. Group 2 deciding on an editing tool for their video clips

Both groups scheduled only their next co-located meeting in advance, using them as points to breakdown the outstanding work into things that could be done individually or in sub-groups, then distributing and scheduling the activities. At each stage they accepted that the full task could not be scheduled from the start, as periods of discovery and creativity were needed in this case.

Group 1 ultimately had four meetings over the three-week period, including the opening meeting when the task was explained to them and a final meeting when they created their video to promote environmental consideration on campus. All four members of the group attended each meeting. Group 2 held five meetings over an equivalent three-week period, which were used for similar purposes to group 1, but had two distinctions: first, in the third and fifth meetings, only two of the four group members were present – in both instances the two absentees were the same people; second, Group 2 needed two meetings (their fourth and fifth) to create their output for the task.

The interpretation of the task by the two groups was slightly different. The first group envisaged a single 90-second video clip to be shown around campus and targeted making a production-quality version of this video, using a mixture of their own film and publicly available clips. The second group envisaged a much grander set of twenty short videos to be played around campus, spoofing famous film roles, such as James Bond and Indiana Jones. However, they only aimed to create a few prototype videos to illustrate the environmental messages that they had scripted.

9.2 Validating the Framework

This section reports a lightweight validation of the schemata using two exemplar meetings from the *PDA Study*. The objectives of the validation are: (1) to test how well the concrete and abstract schemata represent a complex task; (2) to identify improvements that could be made to the framework.

The part of the study that the thesis has focused upon for analysis in this chapter is the penultimate meetings of both groups. The reason for this is that, although both groups are well established by this stage, circumstance made the patterns of disruption in flow very different across the groups at this stage of the task. In particular, in their previous scheduled meeting, everyone had been present for Group 1 but two members were absent from Group 2. This mixture of similarities and differences between the instances provides a good basis for validation of the framework, which is intended to capture both concrete instances of collaboration and meaningful abstractions.

9.2.1 Group 1 Meeting 3

In their previous co-located meeting, the group identified a basic story for the video that they wanted to create. The video would be made partly of free clips taken from the Internet and partly of newly filmed clips, which involved some of the group's members and their friends acting out short scenes. Therefore, coming into this meeting, each group member was returning with the output of these activities. The participants for Group 1 are identified as A, C, P and S.

Chapter 8 defined the concrete schema as having three sections: parameter, resources and activities. Each of these are applied in turn and the fully-described concrete collaborative schema for this meeting appears at the end of this section (see table 9.1).

Collaborative Parameters

The first aspect of the concrete schema that the thesis considers is the task-related collaborative parameters. First, the goal for this group is to create a video clip extolling the virtues of waste reduction. Unlike in the card sort study instances, this goal has been developed during the group's first meeting, but now the group members have a reasonably-clear shared understanding of the goal that they are trying to achieve. There is evidence of this from earlier meetings, but also from the purpose of this meeting, which is to bring together individual work that they have undertaken towards that shared goal. The goal is still *partially negotiable* as there is no evidence that the group know yet exactly what their output will be.

The group members are all partially aware of the task that they have in this meeting; there are a number of reasons for this. First, part of their previous meeting was spent scheduling individual activities to be completed between meetings; therefore they all have a shared awareness that the state of these activities needs to be reported upon. Second, they have a relatively settled goal, so they are more aware of the steps needed to complete it.

However, they do not yet have a clear plan of all the steps required to meet their goal (such as was in evidence in the latter repetitions of card sorting in Chapter 7), so the task plan for this meeting can be described as *partially known*.

Looking at the team-related components of the framework for this instance, it can be seen that there are four members of the group, they are co-located, working synchronously and their work is strongly coupled. Reflecting on how this group works as a whole, it could be argued that its members work partly synchronously and partly asynchronously; however, the thesis finds that it is better to define a collaborative instance as a period where these team-related components remain the same – i.e. any variation signals the start of a new instance of collaboration. The reason for this is that once these parameters change, the activities that individuals within the group perform change, so they are better considered in isolation from each other at the level of a concrete schema; any similarities that persist between the instances will be captured at the level of the abstract level anyway, where it is easier to look for consistent behaviour across different collaborations.

In considering the group phase, this is the third time that the group has worked together, but it is still their first attempt at this task. In complex tasks that run over time it is likely that teamwork will repeat more quickly than taskwork, and this is certainly the case in this study. Therefore, when looking at the group's phase in terms of Tuckman's development sequence, it can be seen that the group is situated around the storming-norming transition; there are already signs of the group having a consistent and structured way of working, but because there are still new task-related issues arising, there is also evidence of storming in previously-untested areas.

The parameters designed to state a numerical measure of previous task and team experience were easy to define for the short, well-defined collaborative iterations of the *card sort study*. In trying to apply them to a complex, multi-session collaboration this becomes much more difficult. The purpose of the numeration is to help identify whether comparisons between different collaborative instances can reasonably be made. One way of translating this to the complex task, and the way taken in this validation, is to say that the group has worked together twice before – therefore, their previous team experience is listed numerically as 2; although they have worked together as a group, the sub-tasks in this meeting are different in substance from those of the previous two meetings, so their task experience is listed numerically as 0.

Collaborative Resources

As this is the third meeting of this group for this task, they now have a lot of shared task knowledge to draw upon. The particular knowledge artefacts that are of importance in this study are as follows: (1) the group members have a shared knowledge of the overall script for the video; (2) the group members all know which activities have been assigned to each of them. What they do not have shared knowledge about is how to edit this together, although they are all aware that A has prior experience of doing this.

The tangible artefacts that are available to the group members are extensive. Each has a PDA, loaned for the duration of the study. In addition C has brought an external hard disk with his work on, and A and P have brought memory sticks with further video clips stored. The group has a desktop computer linked to a large screen and loaded with a selection of software packages for playing and editing digital video recordings.

The norms of behaviour that the group have established so far are centred around attendance, expectation of personal contributions and leadership.

By this third meeting, a number of abilities relevant to the collaboration have become apparent. A in particular, and C to some extent, have both demonstrated ability in film-making: A's abilities are both directorial and technical, whereas C's are primarily technical. Each of the group members now also have some familiarity with the PDA devices they were provided with for the study.

Choosing abilities that are both observable and pertinent to the collaborative work is a judgment call for the person constructing the concrete schema – for example, each of the group members have demonstrated the ability to open the door to the meeting room, but this has been rejected as not relevant to the collaboration; in other circumstances it may be relevant.

Collaborative Activities

At the start of the group meetings, a laboratory technician is available to help the group members copy files from their PDA devices to the desktop computer available in the laboratory. The reason for this is that the transfers are made via Bluetooth and the participants are not expected to have any prior or developed knowledge of this; by comparison, any artefacts that they introduce themselves, they are supposed to be able to use without help.

The timings through this meeting are recorded in square brackets, e.g. [15:30].

[00:00] C arrives first and talks to the laboratory technician, who begins to copy files from his PDA to the desktop.

[02:30] A arrives.

[05:38] S arrives. The others ask if he's seen the final group member, P, but he hasn't. They decide to call him – demonstrating an early attempt to *collaboratively bound the team*, but as they do he walks through the door. The reason that this can be considered to involve 'bounding the team' is because the timely attendance of the meeting is potentially a group norm that is being defined and tested. This illustrates an opportunity that an external observer may have to identify a relevant norm because, as has been previously discussed, norms are often implicitly understood and only observable when someone 'breaks the rule' and is censured by other group members.

[06:33] While they are waiting for the laboratory technician to finish transferring files from the PDA devices the group members, prompted by A, begin to discuss the work that they've done between meetings:

> A – I've done very little everything [sic.]
>
> S – Why?
>
> A – I tried to do it, but you need some other stuff as well, so it's in there…
>
> S – What other stuff do you need?
>
> A – Well … you have to get music, you have to get the title credits, you have to put everything together … I mean, it's there …

It transpires, from how the meeting unfolds, that A and S worked together, away from the co-located meetings, to film their own video clips. So this brief interlude is A informing S of how far he's progressed with some privately-arranged work that they identified together as a sub-group i.e. this is a phase where A decides to *individually monitor the task*. There is a slight disruption in collaborative flow here, which is patched by A trying to bring S up to speed before they present their joint work to the other group members, but what is also apparent is that they have a clear shared understanding of their work; there is evidence for this because A does not have to be explicit on what he's talking about, S already knows.

[06:50] From this, A shifts the conversation by turning to P, and asking:

> A – You got yours?
>
> P – I've got some footage … I didn't have time to put it together, but it's nice … cos, yeah, I also need some other software

Taking these two fragments of the meeting together, the pattern emerging of A leading the group begins to be seen. Leadership can be viewed not only as a role, but in this context where the role is not formally defined it could also be considered to be a behavioural norm that has been implicitly accepted by the group. He is using this period where they're not fully in control of the meeting (i.e. because they're waiting for the laboratory technician to finish his work) to continue to *individually monitor the task*, by identifying the progress that other group members have made since their last meeting.

[07:55] They go back to watching the technician work, before S continues the conversation.

> S – So you've got the footage, but you haven't, er …
>
> P – I haven't put them all together, no
>
> S – Have you filmed yourself?

P – No, I haven't done that … I've got some ideas for that, but we'll see how it fits into the footage

A – OK. Well, put it in and we'll see what you've got. Do you need any special effects for it as well?

P – Yeah. I'm going to need to speed some of them up

A – Mmmm…

P – One of them's already speeded up … which is why I need the others too

This conversation demonstrates the disruptions in collaborative flow that this pattern of group is likely to experience when they meet up. They have all done work away from the group, so there is a lack a shared awareness in these areas. However, the repair of these disruptions is predictable and easy for the group members because they stem from earlier shared decisions. In this case, group members knew what each other was intended to do between group meetings and to repair the disruption all they need to do is monitor these activities and understand any differences between the state they expected and the state that they are actually in. The reparation also represents a point where they shift from the point where A felt he had to *individually monitor the task*, to one where they *collaboratively monitor the task*.

[08:30] At this point, there follows a period of general chat while the technician continues to try to move the PDA-based files to the desktop computer via Bluetooth. There's a problem with the connection, so it takes some time.

[22:00] The technician has now sorted the problem; the group members are left alone. C now connects his external disk to the desktop, via USB. It's not recognised the first time, and the others offer advice on how to get it working.

[24:30] Having seen C successfully copy his video file onto the desktop, A prompts the group to begin:

A – Maybe C should start, cos you're doing the first bit

C – Yeah. *He takes the desktop mouse and starts the clip.*

All the group members are aware that they need to show and explain the videos that they have created; what happens in this event is that A chooses to *individually structure the task*, so that there is now some suggested order for watching the clips.

[24:55] They all watch the video for a few seconds, then S asks:

S – Do you have sound on this one?

C – No

S – Ok

This short exchange represents the start of the group artefact negotiation process – i.e. a point at which they *collaboratively negotiate the task.* C is presenting an artefact (the clip) that is his and he expects the group to adopt it; one of the other group members is indicating that he expected it in a slightly different format. These expected differences are a cause of disruption in collaborative flow, which they resolve as a result of the negotiation process.

[25:50] They watch the remainder of the clip in silence; at the end, the discussion of it begins again.

P – That's good / A- Yes, very nice

S – I think we need a bit longer for the messages

A – I think the messages are ok, if it's playing on a loop

S – Some of them I didn't have time to read

A – I think we should … well *(he looks at C)* have you got any music to go with it?

C – No, I haven't

A – We need some kind of …

S – Yeah

The negotiation process extends to A; they are now considering two possible problems – the lack of music and the sub-titles. The group members have to decide whether to accept this clip and call the activity of creating it complete, or to develop the activity further and pass it back to C. From here, they go on to discuss what type of music might be appropriate. This shows how the group extends for a point where they *collaboratively negotiate the task* to one where they begin to *collaboratively develop the task.*

[26:30] C shows them the clip for a second time, and they begin to discuss the details of the captions.

C – That's four seconds … I can make it five seconds

A – Well, I didn't have a problem reading it, but I guess some people are just fast

S – I'm slow!

P – It depends whether the picture grabs your attention and you start looking …

A – Yeah

P – … and you stop reading the words

S – *Pointing* You see, that was quick

A – … but it gets the point across.

This exchange shows that a variety of ability is important in idea evaluation. The group have discovered through this that S is a slower reader than A. A lack of awareness of differences in abilities can cause disruptions in collaborative flow, as can be seen here when A would have accepted the clip as it stands, but S is unhappy with it. The discussion continues along these lines. This shows that sometimes the needs of the team and the needs of the task are difficult to separate; the group is trying to *collaboratively understand the task* here, but to do so it also needs to *collaboratively understand the team*, because they are trying to judge to impact of their videos according to whether they decide A or S is a representative target user.

[27:55] When the second viewing is complete, A checks the length of the clip with C, as he has an overall plan for the final edit.

A – Ok, pretty good. How long is this whole thing?

C – About one minute

A – Ok, one minute sounds about right

From the pattern of these dialogues, there is evidence that A has been more-or-less accepted as a de facto leader of the group – here he continues to *individually monitor the task*. This demonstrates that the group has, in this respect, moved into the norming phase of their development – the thesis could perhaps even argue that there is some evidence that they have achieved the performing phase; the behaviour throughout the remainder of this meeting should show whether this is true.

[28:00] A prompts for someone else to show their work:

A – Ok, P do you want to show yours, or do you want us to do ours first, or…?

P – I might feel mine's really bad once I see how good yours is

A – *(laughs)* Oh, you won't think that!

This gives evidence that the group is still in the norming phase. They are not yet fully aware of each other's abilities (with respect to the set task) and, as such, are still discovering what they should expect of each other and what other group members view as an acceptable standard of work. This continues to show the same cycle of activities as the earlier part of the meeting, as they continue to monitor each other's work and decide on whether it should be further developed or if it is complete; it also shows the ongoing leadership of A as he tries to *individually structure the team*.

[28:30] P tries to open his file in Windows Media Player and it gives an error.

> A – Oh-oh
>
> S – Ah, Windows Media Player!
>
> A – No codec
>
> S – Yeah, open with VLC

P does this; he already knows how to do so. This is the first serious test of the group's collective knowledge on the manipulation of audio-visual files. It provides an opportunity for the group's members to compare their individual knowledge with that of others and the outcome is explicit group knowledge of their relative abilities with the programs discussed. Here the group try to *collaboratively understand the task*, building shared understanding of the problem towards solving it.

[28:45] The video starts and P narrates his view of it.

> P – what I'm thinking is … there's going to be a scene that we're going to have to act out there that's going to be the machine and the printer running out of paper…
>
> A – Uh-huh
>
> P – … and then I'll probably say 'I'll go and get some more paper' … something like that.

This represents P presenting the output of an activity that he has undertaken individually. He is now looking for the rest of the group to *collaboratively complete the task*, by supporting him in saying that this is relevant to the main task.

[29:05] The first of P's clips end, and S asks:

> S – Are they in order of playing list?
>
> P – No
>
> S – Well put them in order, and we'll have a look

P takes this comment on board, and continues to show and describe his clips. This is a period in the group activity where S tries to *individually structure the team* by giving them roles to perform; the artefacts that P has created remain the same whichever order they're viewed, but the order is important for S in order for him to *individually understand the task*, with respect to P's work.

At this stage of the project Group 1 were more cohesive and had a clearer strategy for producing the video. The meeting observed here was for the four of them to run through video clips and other data that they had collected individually, so that they could come up with a shared idea of what to use in the video, where, and what might still be missing. An example of instructions that were used in Group 1's dialogue is as follows; another group member – C, presents the video clip.

> P – 'This is what we want ... it's already speeded up' (*looking for video of a fast car*)

> A – 'Oh, yeah, good'

The instruction (that this is a clip the group wants) is confirmed by A's reply, and unanimously agreed by the other two group members nodding their approval, giving a further example of how the group members *collaboratively complete the task*.

The video clip can also be considered to be an artefact that has been successfully negotiated into the group domain. The original owner of the artefact was C, who sourced and presented the clip to the group.

[30:00] P shows his clips in the order that he has scripted them. As he shows them, he explains how they link together and the story that he's telling with them. The others question him occasionally about the details, or possible alternatives, e.g. S asks him if a clip of a tree being felled isn't filmed from too far away to be effective:

> S – You didn't find anything without the thing at the front, cos it's kind of blocking the view

> P – No, I don't think that there was a better one than that … but we can add sound of a tree falling down

Now the other group members have seen the clips and they have built some shared understanding of their relevance to the task, S is trying to use the shared knowledge to *collaboratively develop the task* further.

[35:20] Having shown all the video clips, P begins to discuss how they could be used.

> P – It depends how fast we want to make it, but we could use all the same again backwards

> A – Yeah, we could do fast forward / rewind

> P – Yeah, I've got to go back to the paper being made, so we could just use the same clips … and then I guess I have to do a scene where I get back and put my piece of paper in the printer

The group members continue to *collaboratively develop the task* through this dialogue. This also illustrates the general trend through the meeting, where the collaborative flow is increasing as all the little differences in understanding and opinion that have arisen since the last co-located meeting are being worked through and resolved. This discussion continues.

[37:00] Once the group members are happy with how P's contribution fits into the plan, A again prompts to see more work. Here there is a shift to where A tries to *collaboratively structure the team*, rather than trying to do this individually. Again, this supports the idea that collaborative flow is increasing, because the interaction between group members is becoming easier.

> A – *(to S)* Ok, do you want to do it, or me go next
>
> S – You do it
>
> A – Ok *(taking mouse)* there's two bits because there's two Movie Maker files. So we'll start with the first one, which is S's *(an error message appears)* oh, the files aren't here
>
> S – Wait, wait … what happened?

This leads to an argument between S and A about why the clip won't load, and whether A should go and convert the file into another format. S wants A to do this; A doesn't want to. A has control of the mouse and says:

> A – Never mind

A starts the second set of clips – a point where he chooses to *individually develop the team*; these are clips of S acting out some scenes, filmed by A. The development is a progression from the earlier team structuring by A.

[40:20] Having seen the available clips, A and S discuss them.

> A – So, we just need to edit that scene a bit more than the first one.
>
> S – Yeah, but … *(and they revert to arguing about the missing first clip again)*

They agree that they don't need the first clip just now and start discussing what they still need to do. This is another point in to the meeting where the discussion enables the group members to *collaboratively understand the task*, reducing differences in their individual understanding and increasing the collaborative flow within the group.

[41:30] They now have a discussion about what file types they've created. A wants everybody to provide their files as AVIs so that he can edit them together and he moves to *individually structure the team*, instructing each of the team members to do this. The process that the group have gone through to this point has developed the video clips as shared artefacts – they have both a tangible element and associated knowledge that enables the group to identify how they will apply the clips to achieving their goal.

[42:45] At this point in the meeting, they've been through everything that they've done elsewhere as individuals (or, in the case of A and S, as a sub-group). Now A wants to schedule the next meeting:

A – Actions for next meeting, which is when?

S – Er, I kind of can't do before next Tuesday?

A – Which is? What date?

S – It's the 2nd, I think *(he brings up a calendar application on the desktop)* … so, we need to deliver on the 4th, do we need to meet before?

A – At some point, we need to put all the videos together

S – But we can do that the final meeting

A – Ok

S – Shall we make it Wednesday? At 2 o'clock?

A – Ok, Wednesday at 2

The first part of this dialogue shows how the group members A and S try to *collaboratively understand the team* and from this they continue to *collaboratively structure the task*. The two of them assume that they have the implicit approval of the others for this schedule. This shows elements of sub-grouping during this collaboration. The framework makes a distinction between individual and collaborative activities; therefore sub-group activities are described as collaborative but are not distinguished from full group collaborations.

[43:45] Now S has taken responsibility for filling in a record of the group's plan for the next week. He opens a document window on the desktop, records the date agreed with A for the next meeting, and prompts:

S – Right, A?

A – Oh, I have to video film …

P – Wait, did we say 2?

A – Yeah … film the bins and also some scenes with S, plus editing, get the right music and stuff like that

P – Is that video from the PDAs, or is that your camera?

A – My video camera

Although quite late in the timeline of meeting, this shows that the group still needs to work to *collaboratively develop the task*. The structuring by A and S earlier has raised new questions and shows that further disruptions in flow can occur, even when a meeting looks to be heading for a natural conclusion.

[44:30] Now C asks about the music

> C – If we find something, should we use it start to finish?
>
> A – No, I think we should use different ones as each clip has a different feel to it

This is another attempt to *collaboratively develop the task* as each group member looks to *individually understand the task* with respect to any activities that they think they will have to do in between co-located meetings.

[44:45] S brings the group back to the earlier discussion they had about the time that the messages in C's clip were visible; this is another instance of the group members trying to *collaboratively develop the task.*

> S – Do you agree about increasing the message time, some of them at least?
>
> A – Yeah, ok, I mean just find the right timing for it *(he turns to C)* plus music, I guess

[45:30] They try to decide what more they want to film, and throw in some new ideas. They also decide where they're going to film and A makes sure the others know where this is. Next, they move on to when they'll film these clips. Here they are moving away from the phase where they try to *collaboratively develop the task* to one where they *collaboratively distribute the task*. S records all this in the document.

[49:30] They go back to discussing the soundtrack

> A – What kind of music do you want to put with it? Funny, goofy music?
>
> P – I really don't know what's going to work with it or not
>
> *(they pause to think, then A makes some cartoon-like noises)*
>
> P – *(laughs)* Yeah

The final event of the meeting reverts to the group members trying to *collaboratively understand the task*, before they adjourn.

[50:45] The meeting finishes, as A has to leave.

The observations from this meeting have identified a number of points that raise questions about how the framework should be used:

Video clips have been negotiated as group artefacts. This raises two questions about modelling with the framework.   First, (when) should observed developments be added to the resources? The parameters represent the starting state of the collaboration and the activities represent its progress, so should the resources be updated for the progress? Second, should all tangible artefacts have associated knowledge artefact recorded, or should this be assumed?

What group development phase did the group reach? At the [27:55] mark, it was observed that the group reached the 'performing' development phase. (Where) should this be recorded?

Sub-groups were observed. The activities separate between individual and collaborative work, but not between full group collaboration and sub-group collaboration. Is this a further distinction that needs to be made?

The answers to these questions are considered in section 9.3, which reflects on the framework as a whole and suggests revisions to it.

Table 9.1. Concrete Collaborative Schema for PDA Study Group 1 Meeting 3

CONCRETE COLLABORATIVE SCHEMA			
description			
This is the third in a series of scheduled meetings for Group 1.			
parameters			
task		team	
Goal:	partially fixed	Number:	4
Task plan:	partially known	Location:	co-located
Task experience:	0	Synchronicity:	synchronous
		Coupling:	strong
		Phase:	storming/norming
		Team experience:	2
resources			
Knowledge artefacts:	Overall script of video, Activity assignments		
Tangible artefacts:	PDA, external hard disk, memory sticks, desktop comp., large screen, editing s/w		
Norms:	Attendance, Personal work schedules, De facto leadership		
Abilities:	Directorial and editorial film making		
activities			
Collaboratively bound the team			
Individually monitor the task (observed 3 times)			
Collaboratively monitor the task			
Individually structure the task			
Collaboratively negotiate the task			
Collaboratively develop the task (6)			
Collaboratively understand the task (4)			
Collaboratively understand the team (2)			
Individually structure the team (3)			
Collaboratively complete the task (2)			
Individually understand the task (2)			
Collaboratively structure the team			
Individually develop the team			
Collaboratively structure the task			
Collaboratively distribute the task			

9.2.2 Group 2 Meeting 4

Although there have been three previous co-located meetings for this task, this group as-is has only formed for two of these. The most previous co-located meeting only took place between two of the group members, due to unavailability and illness. This was allowed to continue by the administrators of the study because they felt that this reasonably modelled the problems of attendance faced in the workplace every day. What this meant was the group members had a very uneven understanding of the current position of the task – despite the fact that the absent members had been sent e-mails informing them of the progress. The participants for Group 1 are identified as F, M, T and P. In the meeting between only two members – F and M – they had scripted the details of three of the mini videos that they wanted to film. The fully described concrete collaborative schema for this meeting appears at the end of this section (see table 9.2).

The meeting here has a split in the middle where the group go off to record their video clips, resulting in around a 15-minute absence from the laboratory. It could be argued therefore that this represents two consecutive meetings, as some of the task- and team-related components must have changed during the brief period of absence. Because of this, the thesis will reflect on the possible impact of these changes at the break point and discuss whether it is more appropriate to view this as a single meeting, or two linked events.

Collaborative parameters

Again, this section of the thesis begins by first considering the parameters of the collaborative schemata framework. As with the comparable Group 1 meeting, this meeting comprises a group of four, who are co-located, working synchronously and their work is strongly coupled.

Because the objective for both groups was deliberately both complex and vague, their understanding of the goal has now diverged quite markedly. Like the first group, the second is developing video, but the content and aims of both are quite different. As such, their understanding of the activities needed to complete the task is different too – although the profile remains the same in some respects: like the first group, they are convening in part to discuss previously-scheduled activities and, also like the first group, they have a reasonably settled goal, so this is recorded as a *partially fixed* goal and a *partially known* task plan.

This group, like Group 1, have met twice before; so this is their third time of working together, although they are still working on their first trial of the task. From the observations, it appears that this group is still more entrenched in the *storming* phase of development, so is slightly behind Group 1 at this stage. The literature on group phase development indicates that every time someone is added or removed from an established group, then that group has to begin again from the forming stage – although it will likely move through the phases more quickly. Similarly, temporary absences can cause contention, as some group members develop shared ways of working without the approval of others.

Collaborative resources

What is apparent in comparison with Group 1 is that there is no-one in this second group with experience of manipulating video clips, but T does have his own camera and is experienced in using that, so filming is recorded as an ability. The group members have also brought some scripts for the films they intend to make, so scripting is included too.

As the thesis has already stated, the task-related knowledge within the group as they start this meeting is uneven, because of the absences at the previous meeting. Consequently, their shared task knowledge partially represents an earlier snapshot of where they were with the task two meetings ago, with some fill in from asynchronous communication (i.e. e-mails) between the members.

This group shares two of the norms identified in group one – they have some sort of rule that governs attendance and they all appear to adhere to personal work schedules drawn up collaboratively within the group. Unlike Group 1, there is no strong evidence of a de facto leader.

This group has a number of tangible artefacts that are the same as those used by Group 1, and some that are different. Like the other group, each participant has a loaned PDA that provides the functionality that the study design envisaged them needing prior to commencing the task; they also have the same desktop and large screen for demonstrating, collating and editing their video in the laboratory. Unlike Group 1, at this stage they have not brought any external disks or memory sticks – possibly because they intend to do their filming as part of this gathering. Additionally, one of the group members – T – has brought some props that he anticipated would be needed for the filming.

Collaborative activities

[00:00] P, F and M are present in the room with the laboratory technician.

[00:15] The final group member, T, arrives.

T – I've brought a bottle

F – Your Technicolor camera

T – My Technicolor umbrella! It's not a camera…

The negotiation of artefacts into the group is a good mechanism for reducing or eliminating disruptions in flow. By either choosing an artefact or redefining an artefacts purpose within the group, the group members develop a clear, shared understanding of what the group is doing and what are the outstanding activities – this process helps the group members to *collaboratively understand the task*.

In the following discussion, which all four members of Group 2 make a contribution to, the group is deciding whether to use a video camera or one of their PDAs to go out and film the spoof prototypes. In this phase the group members *collaboratively negotiate the task.*

> T – I've brought a bottle
>
> T – 'My camera's in the car. I thought with this rain we wouldn't be bothering with much.'
>
> P – 'we can film in the rain.'
>
> F – 'Well, er, T just said...'
>
> T – 'The camera's in the car'
>
> P – 'We can film with the PDA'
>
> M – 'Yeah, we can film with the PDA'

This discussion illustrates another interesting aspect of group artefact adoption. Any artefact being adopted by a group needs to be introduced by an individual, and that needs to be done willingly. There is evidence here that T was asked to bring his camera in a previous meeting (and, indeed, this was true), but he is unwilling to make a genuine effort to introduce it to the group.

This leads P to sponsor a different artefact – the PDA, a move that is supported by M and they *collaboratively negotiate the task*, which results in the acceptance of the PDA as the correct tool for filming.

[01:00] They've decided to make the films, despite the poor weather and F wants to move the discussion forward:

> F – That's it? Let's make decisions here then.

F tries to list out what they need to do, but T is not up to speed. F gives T a printout of an e-mail that M sent that morning and the others chat while T reads it. Because of this disruption in flow, F has to try to *individually structure the team* while the group members as a whole work to *collaboratively understand the task*.

[02:00] In earlier meetings, the groups negotiated a number of roles required for teamwork. This could still be necessary, but the groups in this study needed specific task-related roles at this stage of their development.

As well as traditional team roles, task specifics often create the need for new roles that need to be defined by the group members as they progress the task. In the case of Group 2, because they had the idea of spoofing stars of screen in their video prototypes, they needed to cast these roles.

Until the moment the following questions was asked, the idea of how this was going to be achieved had remained abstract and no-one had chosen to address the absence of these defined roles within the group.

F – ‘So who is going to be Indiana Jones?

The role definition and negotiation is aimed at closing a disruption in flow.

Firstly, a script has been created for the role, but not everyone understands how this is going to play out. Secondly, not everyone understands what props are going to be used to make this happen.

(scripting Indiana Jones)

F – ‘Ok, what does he do?’

M – ‘I just walk in’

F – ‘Walk in with what?’

(rephrase)

F – ‘What are you recycling? Oh, the cans’

.....

F – ‘What do we do for the whip?’

P – ‘We’ve got some wires round here ... just whip it’

F – ‘OK’

The second part of the scripting dialogue begins with a question, but the event also includes the acceptance of another group artefact. This shows how negotiating artefacts into groups can fundamentally alter their properties, as the cables now have a purpose fit only for the upcoming activities. This dialogue also shows how the group members both *collaboratively develop the task* and *collaboratively develop the team* at the same time; the task development is the improvement in the script and the team development represents the new temporary roles that are identified here.

Also, the group members are building a shared knowledge of the characters that they have selected to ‘star’ in their videos. The knowledge artefacts that they are developing are not only a shared understanding of the character, but of each character’s application towards the goal that they have defined.

[03:00] They now discuss the props that they need for the Indiana Jones script and move on to James Bond; P volunteers T this time, who again accepts. This is developed using the same types of collaborative activity as in the previous meeting fragment, i.e., they *collaboratively develop the task* and *the team*.

[05:30] After a little discussion, F wants to know if T understands what he is going to enact as James Bond later.

> F – *(checking script with T)* So, is that ok?
>
> T – Err…. *(he pauses)*
>
> F – So what are you doing? Camera's there *(he gestures to an imaginary location)* You come in … I mean, you have the bottle there. You come in. You recycle it.
>
> T – Look at the camera…
>
> F – and then, you turn to the camera *(he starts making gestures of adjusting an imaginary bow tie)*
>
> T – …and walk off
>
> F – Bow tie, hair and you go out.

The plan for this activity has already been made and the group have a script for it. In this exchange, F is already assuming that the plan has been successfully negotiated into the group and is only making a casual check with T. When he realises that T is not sure what the plan means, he initiates a process where they move to *collaboratively understand the task*. This also represents the reparation of a disruption in collaborative flow that has principally been caused by T's absence from the last meeting.

[06:30] They move on to discussing which props they have and what else might be needed, e.g.,

> T – I don't have a jacket

With this statement, T illustrates that disruption in flow has been repaired and now that they have the shared understanding he *individually develops the task* by developing the requirements for this planned activity.

[07:15] F is still controlling the meeting. He now checks that they have all the audio files that they need for their scripted clips. Then he moves back to checking the props

> F – Do we have something to recycle?
>
> P – A PDA? *(Everyone laughs)*
>
> F – Paper!

This is further development of the activities that are already planned. This time, F asks an open question to the rest of his group and they *collaboratively develop the task.* Additionally, the joke about recycling the PDA is an example of where they *collaboratively bound the team* – i.e. they have identified a shared value.

[08:45] They move on to a discussion about how to film the clips.

> F – So, what camera do we use? That one *(he points to a camcorder in the laboratory)*
>
> P – No, we were going to use…
>
> T – …use the PDAs
>
> F – Oh, ok
>
> T – You've worked out how to use them to get videos?
>
> P – Yeah

M now demonstrates to F how to use the PDA for video. This is another point where shared understanding is required – the group have already planned this. Again though they suffer from a disruption in collaborative flow – F is expecting T to provide a video camera, but the others have decided to use a PDA to film the clips. This shows that there is a loop where the group work to *collaboratively understand the task* in order that they can *collaboratively negotiate the task* and this negotiation leads to further understanding. This is the process that the thesis identified in Chapter 4 as the development of group knowledge artefacts.

[09:30] M and F leave the room to get props for the filming. While they're away P and T work out how to see the amount of battery life remaining on a PDA. After this, they slip into a general chat.

[10:45] M and F return.

[11:15] Now T wants to know how to use the camera.

> T – How do you use the video on these?
>
> F – Oh here, ok, so you press this button *(points)*
>
> T – This button *(confirms by also pointing)*
>
> F – Er, ok, it's off … sorry … and then I think here

They go on to discuss which way around they're going to hold the PDA, and how this will affect the final picture. They're not sure, so F creates a test video and plays it back. They use this to discuss what they're going to do. All the members of the group continue to practice creating and playing back videos, showing each other things or asking questions as they build some experience with the device. This passage shows how quickly group members can switch between related individual and group work. As they practice with the PDAs' video function, they are trying to *individually understand the task*, and when they find something interesting to share, then they are performing the same activity at a collaborative level. By identifying functions that they think are relevant and demonstrating them, they are also each trying to *individually structure the team*.

[15:15] One of the problems they encounter is that the PDAs don't appear to record any sound with the video clips.

> P – I can't hear anything *(playing back a test video)*
>
> F – Yes, but we don't need the sound … we're using music and …
>
> P – …but we'd have to record the voice afterwards
>
> M – What voice, we're not…
>
> F – Oh, he's saying something. He's the only one saying something *(pause)* What we can do, we can use the film version.
>
> P – Yeah, yeah
>
> F – Hasta la vista!
>
> P – Yeah, that's fine

This short passage illustrates the disruption in collaborative flow that has arisen from the group members taking time to individually work with the PDAs in order to learn their functionality. They have each, to some extent, used their new knowledge to *individually develop the task* and only when they try to extend this to a collaborative level do they build a shared understanding that shapes the final development, which results in them being able to *collaboratively develop the task*.

[15:45] They continue to work out how to use the devices, both as individuals and as sub-groups, asking questions when necessary.

[16:40] They reach a point where P wants to get going with the filming.

> P – Right, are we doing this, or what?
>
> M – Yes.
>
> P – Let's go do it.
>
> F – Just a minute, because er…
>
> T – Here it is … unspecified error
>
> F – Yeah, you have a problem with yours
>
> P – Really?
>
> T – Let's ignore this one, and use the other ones instead.

M – If F knows how to do it, he can do it on his … and F just films each one

From this, they go on to another discussion about which way up to hold the device. This passage of interaction begins with P trying to *individually structure the team* so that they move to a phase of task activity.

[18:15] F finds the laboratory technician and tells him the group are going to do some filming and the group members gather up the props that they need and leave.

[32:15] The group members return to the laboratory. To begin with, they're just chatting, then they want to copy the video clips from F's PDA to the desktop computer. The laboratory technician helps them do this, using the PDA's docking station and ActiveSync software.

[33:45] F plays the first clip. He plays one of his practice videos first, but then finds the file that he wants. When it starts playing, T says:

T – Oh, this looks very YouTube *(followed by lots of laughter as they watch the clip)*

F – Oh, the quality's terrible. Well, it's there.

P – Yeah

The group have arrived back to the laboratory having executed a number of activities that they planned and developed in the first part of this session. Because they attempted these activities together, they have returned to the meeting with some sort of plan what to do next, but it is clearly not fully formed and F takes control of the meeting; by controlling the shared computer, he is able to *individually structure the task* and the others follow this lead, allowing them to *collaboratively develop the task*.

[35:00] As they cycle through the new video clips, F changes the file names to something meaningful. He confirms these meanings with the group, e.g.

F – This is Indiana, yeah?

They watch and discuss the remaining clips, a process that allows them to first attempt to *individually understand the task*, before the group discussion enables them to *collaboratively understand the task*, building shared group knowledge from their individual opinions.

[36:30] Once they've looked at all the clips, F wants to know how they're going to edit them all together.

F – So, do we have software here to mix these things?

(They find Windows MovieMaker on the desktop)

P – Yeah, that's easiest to use

They then find a second editing tool, called uLead, and discuss which they're going to use. The identification of these resources enables them to *collaboratively develop the task* by matching the resources to their outstanding known activities (in this case, the knowledge that they need to edit the clips into complete videos).

[38:00] They have some problems getting the video files accepted by the editing software, so they find and use a conversion tool. The clips are short, so this doesn't take very long. Then they can't find the converted files – P uses his knowledge of Windows to direct F to where they've been created in an activity that enables him to *individually structure the team*.

[40:45] Once the converted files have been located, group members start to give instructions to F, as he has hold of the mouse and therefore controls the desktop.

T – Copy them onto the desktop, or anywhere.

P – Try opening it

T – Now open it in the windows Movie Maker

P – Yeah

They continue to try to instruct F to get the file working, but they get further errors. In trying to get this working, they are trying to *collaboratively understand the task* – i.e. there is clearly a problem to be solved that is not yet fully understood by the group; additionally, they are in a situation where they need to *collaboratively monitor the task*, because as they have no expertise in video editing, it is not clear yet if the errors are operator mistakes or a lack of knowledge.

[41:30] F tires of being instructed, and says

F – I don't think the conversion was correct, otherwise why can't you play an AVI file?

T – You can't always…

They try the other software, uLead, now, first with the converted avis and then with the original files. It still doesn't work. This phase is the same activity set as the previous one, with the group *collaboratively understanding the task* and *collaboratively monitoring the task*.

[42:45] F is now convinced that the conversion was the problem.

F – The conversion wasn't right. The problem was the conversion.

They go back to the conversion software and start playing with the parameters. Everybody gets involved, although nobody seems to be drawing upon any prior experience. Because of their difficulties, the group members gradually shift from trying to *collaboratively understand the task* to trying to *collaboratively understand the team*. If they cannot solve this problem, then they need to identify abilities as well as new activities that will allow them to get around it a different way.

[44:00] They get the laboratory technician involved and have a discussion with him. The discussion ends with the laboratory technician unable to help, and he leaves saying

> Lab. Tech. – It's your task, it's your problem.

[50:00] The group take this on board and decide to make one last try at converting the files to a suitable type for the editing software. They Google the conversion type needed and download and install another freeware conversion program. Ultimately, this doesn't work either and, running out of time, they adjourn the meeting.

The thesis shows that there is strong evidence for treating this meeting as a single co-located session, even though there was a break in the middle where the group went out to shoot some video clips. The reason for this is that insufficient of the teamwork and taskwork components had changed between the first and second convening in the laboratory. This second collaborative instance also supports the questions that were identified about the framework when forming the first collaborative instance. These questions are addressed in section 9.3.

Table 9.2. Concrete Collaborative Schema for PDA Study Group 2 Meeting 4

CONCRETE COLLABORATIVE SCHEMA			
description			
This is the fourth in a series of scheduled meetings for Group 2.			
parameters			
task		team	
Goal:	partially fixed	Number:	4
Task plan:	partially known	Location:	co-located
Task experience:	0	Synchronicity:	synchronous
		Coupling:	strong
		Phase:	storming
		Team experience:	2
resources			
Knowledge artefacts:	Overall script of video, Activity assignments, Script characters		
Tangible artefacts:	PDA, desktop comp., large screen, editing s/w, props		
Norms:	Attendance, Personal work schedules		
Abilities:	Filming, scripting		
activities			
Collaboratively understand the task (observed 7 times)			
Collaboratively negotiate the task (3)			
Individually structure the task (2)			
Collaboratively develop the task (6)			
Collaboratively develop the team (2)			
Individually develop the task (2)			
Individually understand the task (2)			
Individually structure the team (3)			
Collaboratively monitor the task (2)			
Collaboratively understand the team			
Collaboratively bound the team			

9.3 Abstractions from the Concrete Schemata

This section builds an abstract collaborative schema (see Table 9.4) to represent a generic *PDA Study* based upon the concrete schemata developed earlier. The collaborative parameters of the two concrete schemata are very similar – the only difference is the group development phase for Group 1 was slightly further past storming than it was for Group 2. The design decision made for the abstract schema was to aim for a development phase of storming/norming, but from a choice of two this is somewhat arbitrary. The choice revolves around whether the observer thinks that the abstract schema is better modelled leaning towards the performance of Group 1 or the performance of Group 2.

The resources chosen for the abstract schema represent the knowledge artefact, tangible artefacts and norms shared by the two groups.

Next the activities are detailed, looking at examples of each category of activity type in turn. Table 9.3 lists the activity types that are shared between the two meeting instances.

Table 9.3. Activities shared in PDA Study between Group 1 Meeting 3 and Group 2 Meeting 4

Collaboratively bound the team
Collaboratively monitor the task
Individually structure the task
Collaboratively negotiate the task
Collaboratively develop the task
Collaboratively understand the task
Collaboratively understand the team
Individually structure the team
Individually understand the task

Understand

The repositories of shared knowledge artefacts that the two groups built during these meetings were very different. This is always going to be the case in complex tasks, because even with an identical brief, the uncertainty of the task leads to divergence very quickly. However, that does not mean that the way they build these repositories need be very different. At the start of both these meetings, because individual work had been undertaken on behalf of the group, the shared understanding came from individual presentations of information; later in the meetings, the shared knowledge was emergent from the activities performed in the meetings.

Both meetings had numerous instances where the group members were trying to *collaboratively understand the task*. This was expected, because the task was both complex and unstructured, so the group members still had work to do in understanding their task at this halfway point in their respective projects. There were fewer occasions when this became an *individual* activity, but this did occur in both meetings and illustrated how sometimes it appears necessary for co-located group members to work on their own understanding, before they try to extend that to the group.

There were also instances in both meetings where the group members were trying to *collaboratively understand the team*. Changes in understanding the task naturally lead to new challenges; these in turn lead to team-mates needing to know different things about each other to meet the new challenges.

Bound

There was surprisingly little evidence of group members either *individually* or *collaboratively bounding the task*. The reason for this may be that both groups had developed their task understanding in previous meetings to a point where the boundary of the work required was reasonably well established and static. For example, Group 1 had already decided upon and produced a script for their video and brought many of the clips required to edit it together; Group 2 were no so far forward, but they also had scripts for the videos that they wanted to produce. Therefore, the new understanding built in these meetings may not be at the boundary of their respective tasks.

Both groups demonstrated ongoing examples of *collaboratively bounding the team* – an activity that builds the group's interpersonal relationships and norms. This fits with other high level observations of the groups, which would suggest that at the stage of these meetings they were both in the norming phase of development, where they were establishing in a positive way how to work together more effectively.

Structure

The profile of how the groups structured their activities was reasonably similar, and the reason for this appears to be the position of the meeting in the timeline of the whole task attempt. Both groups *structure the task* in two main phases. At the start of the meeting, they structure the activities that they need to complete within the meeting, i.e. those activities that allow them to work through what they have each done away from the group in a coordinated manner. Then, in the latter stages of the meeting, they need to structure the next batch of activities that they've identified, i.e. those that will be completed outside the meeting prior to the next time they are together.

The task structuring at the start of the meetings was performed individually in both cases. The reason that this happens in Group 1 is that A appears to lead the team throughout, because of his greater knowledge of producing film. The reason that the same thing happens in Group 2 is less clear, although it may be as a result of previous absences, leaving F – who was present at the previous meeting – to provide the continuity; alternatively, F may be becoming the established leader for Group 2. The number of instances where these two *individually structure the team* in their respective groups lends further evidence to the idea of them becoming de facto leaders.

Develop

The main similarity between the groups in activity development that was observed was the contributions made at the start of the meetings, when individuals presented the output of work performed between meetings. Both groups used the disruption in collaborative flow at the start of the meeting to challenge the work that had taken place and develop some of the activity requirements further.

There were, however, many examples of both groups *collaboratively developing the task*. This strong similarity between the two group meetings could be because of the meetings' purpose – which in both cases was to bridge between periods of distributed, asynchronous work as individuals.

Team development was more of an individual activity – directed by A – in Group 1 and a collaborative activity in Group 2. The reason for this could be that looking at the Group 1 meeting, A has a clear vision for the group's product, whereas in Group 2 this evolves more as the larger initial disruption in flow is managed and reduced, allowing the group members to develop their group roles as their shared understanding of the task improves.

Distribute

In the observed group meetings, there was little evidence of either task or team distribution activities. Group 1 did *collaboratively distribute the task* at the end of their meeting, sharing out activities to take away. This did not happen in Group 2's meeting, possibly as a result of the technical problems that they experienced towards the end of the meeting.

Complete

Only Group 1 showed evidence of explicit task completion. There were two instances where they attempted to *collaboratively complete the task* and both of these were situations where someone had brought in video artefacts that could be negotiated into the group as shared artefacts and then accepted as the solution to some part of the overall task. The reason that there were no comparable activities in Group 2 was because the first part of their meeting was a planning phase for activities that they anticipated that they would complete later – however, again because of the technical problems they encountered, they were not able to do so.

Negotiate

The observed instances of negotiation in both group meetings were those where the group members *collaboratively negotiate the task*. In both cases this represents group artefact adoption, although in the case of Group 1 the artefacts being adopted are clips that are then used for task completion, whereas in Group 2 the artefacts being adopted are to facilitate activities that will be executed away from the co-located meetings.

Monitor

The way in which activity progress was monitored was quite different for the two groups, with very few areas of commonality. The reason for this was again the abilities difference between the groups – i.e. Group 1 primarily relied upon A to monitor the activities, because his ability to edit the clips meant that they all needed to deliver to his requirements; Group 2, on the other hand, were more open and there was much more evidence of all group members monitoring each other's work and questioning its relevance.

One activity in Group 1 was observed as an example where the group *collaboratively monitor the task*; this occurred as a result of A having worked with S on an activity away from the co-located setting. Because of this, there seemed to be more trust between them over a particular phase of the group meeting, which enabled more collaboration. At this time, the way in which the two groups monitored each other's work was more similar.

Execute

Task execution (in the sense of activities that are directly related to and progress the task) was not a focus for either of these meetings.

The activities chosen as core for the abstract model are the ones shared by the two concrete schemata and the auxiliary ones are those that only appear in either/or schema. As with the abstract schema built for card sorts in Chapter 8, this is a design decision that could be modified according to the purposes of the person building the abstraction. If one concrete schema was considered to represent a more effective collaboration, then more may be taken from it in building the abstract schema. Also, as with the card sorting, more concrete examples may alter the choices made and would almost certainly reduce the set of what is considered 'core'.

Table 9.4. Abstract Collaborative Schema for PDA Study

<table>
<tr><th colspan="4">ABSTRACT COLLABORATIVE SCHEMA</th></tr>
<tr><th colspan="4">description</th></tr>
<tr><td colspan="4">This is the abstracted model of collaboration for observed meetings in the PDA study.</td></tr>
<tr><th colspan="4">parameters</th></tr>
<tr><th colspan="2">task</th><th colspan="2">team</th></tr>
<tr><td>Goal:</td><td>partially fixed</td><td>Number:</td><td>4</td></tr>
<tr><td>Task plan:</td><td>partially known</td><td>Location:</td><td>co-located</td></tr>
<tr><td>Task experience:</td><td>0</td><td>Synchronicity:</td><td>synchronous</td></tr>
<tr><td></td><td></td><td>Coupling:</td><td>strong</td></tr>
<tr><td></td><td></td><td>Phase:</td><td>storming/norming</td></tr>
<tr><td></td><td></td><td>Team experience:</td><td>2</td></tr>
<tr><th colspan="4">resources</th></tr>
<tr><td colspan="2">Knowledge artefacts:</td><td colspan="2">Overall script of video, Activity assignments</td></tr>
<tr><td colspan="2">Tangible artefacts:</td><td colspan="2">PDA, desktop comp., large screen, editing s/w</td></tr>
<tr><td colspan="2">Norms:</td><td colspan="2">Attendance, Personal work schedules</td></tr>
<tr><td colspan="2">Abilities:</td><td colspan="2"></td></tr>
<tr><th colspan="2">core activities</th><th colspan="2">auxiliary activities</th></tr>
<tr><td colspan="2">Collaboratively bound the team</td><td colspan="2">Individually monitor the task</td></tr>
<tr><td colspan="2">Collaboratively monitor the task</td><td colspan="2">Collaboratively complete the task</td></tr>
<tr><td colspan="2">Individually structure the task</td><td colspan="2">Collaboratively structure the team</td></tr>
<tr><td colspan="2">Collaboratively negotiate the task</td><td colspan="2">Individually develop the team</td></tr>
<tr><td colspan="2">Collaboratively develop the task</td><td colspan="2">Collaboratively structure the task</td></tr>
<tr><td colspan="2">Collaboratively understand the task</td><td colspan="2">Collaboratively distribute the task</td></tr>
<tr><td colspan="2">Collaboratively understand the team</td><td colspan="2">Collaboratively develop the team</td></tr>
<tr><td colspan="2">Individually structure the team</td><td colspan="2">Individually develop the task</td></tr>
<tr><td colspan="2">Individually understand the task</td><td colspan="2"></td></tr>
</table>

9.4 Reflections on and revisions to the framework

In a concrete schema, the *parameters* and *resources* sections are intended to represent the ‘pre-condition’, i.e. the collaborative state of the group before they perform any of the *activities* recorded in the final section. There are two issues with this approach that are illustrated by the validation process in this chapter.

First, because the session is longer than the iterations of the card sort study, the validation shows that the absence of a ‘post-condition’ set of *parameters* and *resources* means that the schema fails to capture the observed collaborative state of the group at the end of the period of observation. In the *PDA study* this is much more important information than in the *card sort study*, because the co-located sessions are punctuated with large periods where the group members are not together. Therefore, one of the things that a GSS designer would have to understand – if they were designing for the co-located part of these groups' work – is whether significant changes occurred in a group's collaborative state between finishing one meeting and beginning the next one.

Revision #1. Have separate pre- and post- states for the collaborative parameters and resources. Changing the model to have these two states, with the activities describing the transition would enable an observer to capture more accurately in a concrete schema what the collaboration achieved. The knock-on effect for any abstract schemata would be that they would also more accurately demonstrate the intention of the abstraction. Design choices could be made and illustrated in the schemata to show the transition that a designer wanted to support and the steps required to make it.

The second issue is the problem of accurately capturing the 'pre-condition'. Some of the parameters are relatively straight-forward, such as the number of people in the group, or whether they are co-located, etc. However, some others require prior knowledge, such as whether the team has worked together before and yet others are judgment-based, such as the group phase.

It is not unreasonable to expect that anyone observing a collaborative instance with the objective of creating a concrete collaborative schema will develop some of the pre-condition from what they observe during the meeting. For example, an artefact (knowledge or tangible) may be observed some time during a meeting, but the group's members' behaviour may suggest to the observer that it was already a group-owned artefact. Similarly, this may occur with abilities or norms, which are often only apparent when censorship takes place.

However, this does not overcome the issue that if the observer is trying to build a schema for a group that they do not know, or one that is well established, then determining factors like experience will be difficult. Although this cannot be overcome fully, if the observer is intent on building schemata for established groups, then they can overcome their initial lack of knowledge in two ways: either interview the group members prior to the first observed collaboration to try to add depth to the pre-condition; or build schemata from the first observed collaboration, but discard early instances as insufficiently complete.

Revision #2. Develop a formal method for capturing the pre-state. Whichever way this is approached, it is clear that a better structured way of capturing the pre-state would be beneficial to observers and also a useful step towards developing the framework into a design method.

Two other issues were identified during the validation. First, it appears that tangible artefacts always need associated knowledge to have value in a group, so the question was posed as to whether both the tangible and associated knowledge artefact should be recorded or the knowledge about a tangible artefact should be an implicit assumption. Second, the issue of how sub-groups are represented in the framework was raised.

As more method is developed for the framework the issue of matching tangible and knowledge artefacts will be answered more clearly. However, there is evidence that the relationship is not always 1-to-1, so the suggestion from work so far is that they remain separate. Sometimes a tangible artefact is used for more than one purpose in a collaboration and sometimes several artefacts need to be joined together to achieve a single purpose and that purpose would define the boundary for a knowledge artefact.

The observation of sub-groups in the validation led to the question of whether these need to be represented separately in the framework. At present, sub-groups can be represented through collaborative activities, so only further studies could determine whether this is sufficient for the needs of the framework.

9.5 Patterns of Disruption in Collaborative Flow

Group 1 had all four members of their team present at the previous co-located meeting a week prior to the one being analysed, whereas Group 2 only had two of their four members present. In the co-located meetings being focused on, all members were present for both groups. However, Group 1 worked in a way that suggested they steadily built shared understanding throughout their meeting, whereas Group 2 had a series of breakdown points.

The pattern for Group 1, where the disruptions in flow have only occurred from independent distributed work between the meetings is one of a general closing of the gap in shared understanding of the group's taskwork. The pattern for Group 2 is more of a constant wave, where the disruption in flow actually increases at points in the meeting, because closing one disruption actually creates further disruptions in other parts of the taskwork. In this group, the disruptions in flow have occurred through both independent distributed work and what was effectively a co-located sub-group in the previous meeting, due to absences.

The difference in patterns, shown in figure 9.3, illustrates that what appeared to be a large disruption in flow, caused by absence from the previous meeting, is in fact a collection of many smaller disruptions in flow, each of which is dealt with in a relatively sequential manner.

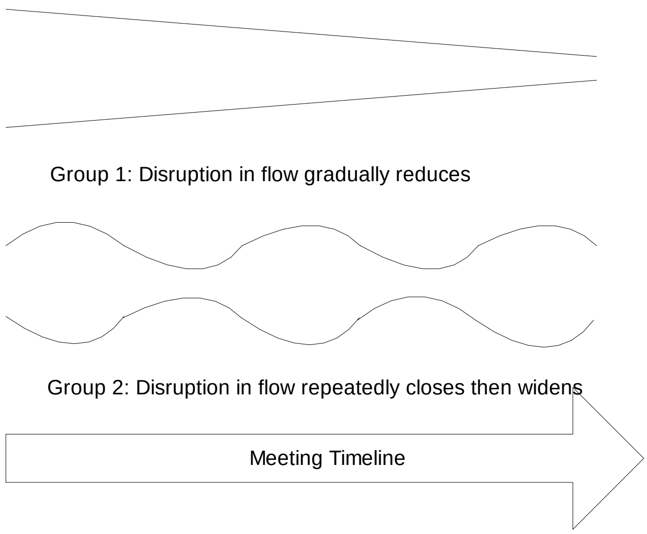

Figure 9.3. Patterns of disruption in flow observed in the group meetings

The reason for these different patterns of disruption appears to be the previous absences. Group 2 experience a series of breakdowns in understanding because the shared understanding between those present in the last meeting has moved away from that of the absentees. By comparison, Group 1's disruptions are primarily as a result of the distributed, asynchronous work that they have undertaken on behalf of the group between meetings. However, these activities were all structured from the previous co-located meeting, at which they were all present, so they have a shared structure through which they can introduce their individual work.

9.6 Conclusions

In this chapter the thesis has tested how the collaborative schema framework can be applied to complex tasks, first by describing specific observed instances of collaboration and second by showing how these particular instances can be abstracted to illustrate a prototypical generic collaboration. The validation identified a series of improvements that could be made to the framework, which are discussed further in the following chapter.

In applying the schema to meetings that represented ongoing instances of attempts to solve a complex task, it was found that prior group activities has reduced parts of the task to much more bounded and easily understood sub-tasks. This meant that there were a number of points for comparison between those meetings and the much simpler group-task instances in the card sort study. To achieve this, however, the PDA study groups had evolved further in terms of their group development, and this made it harder to find points of comparison across team-related activities.

In the next chapter, reflections upon the thesis as a whole are made, identifying the contributions that it makes to the corpus of knowledge on collaborative work. Also, the limitations of the studies are considered and how far this allows generalisation from the work undertaken. From these reflections, a discussion is made of what further work could be done to develop the ideas presented here.

10 Conclusions

This chapter reflects on the findings in this thesis, discusses their limitations and their generalisability and suggests the possibility of future work that could add to the work presented here. The collaborative schemata framework is discussed first, as it is the main contribution of the thesis; this is followed by the taskwork model and the conceptual analysis of collaborative flow as the main supporting theoretical contributions towards taskwork and teamwork respectively. The chapter concludes by briefly discussing the next steps that are planned to develop and extend the work presented here.

10.1 <u>Collaborative Schemata Framework</u>

10.1.1 Contribution

The collaborative schema framework draws together the research findings from the earlier parts of the thesis and uses them to build the components of a two-tier framework. The framework has a concrete tier that semi-formally describes a particular collaborative instance and an abstract tier that describes commonality between sets of concrete schemata. The schemata draw together extant literature on collaborative groupware and also use the thesis' studies of efficacy, complex taskwork and collaborative flow to provide a comprehensive framework that can be used to record both the states and the actions that contribute to a collaboration.

Concrete schemata contribute to the design of new support systems by providing an effective means of recording a semi-formal analysis of an observed collaboration. They capture a starting state of a collaborative instance and the activities that alter that state during the collaboration; future work (discussed later) will also add a representation of the closing state of the collaboration.

The abstract layer of the framework extends this; the teamwork and taskwork factors in various collaborative schemata can be used to develop domains over which common activity types can be analysed. The activity types then provide a structured way of assessing the range of collaborative activities undertaken in certain sets of collaboration.

10.1.2 Limitations

At present, the framework is amethodological; although it has been applied through a validation process and a reasoned argument has been proposed as to how this would be useful to GSS designers, there is not yet an established method for using the framework in design. This limitation would probably be most apparent if designers need to rely on concrete collaborative schemata created by other people in order to develop their own further concrete or abstract schemata; in this case, they would need to be sure that the method of development was harmonious to their own, otherwise the resultant abstractions may not be representative of the designer's needs.

In earlier working of the collaborative schemata, attempts were made to add environmental factors into the framework. This did not seem to fit with the frame of parameters, resources and activities. It suited the semi-formality that is required for capturing a resource, but conceptually felt like a more complex parameter. As the environment in the studies in this thesis was relatively consistent, it was not something that could be explored easily within the constraints of the project so it was dropped. It may be, however, that environmental factors are a useful way of further developing the framework.

A complication of experience in group work that was not fully explored by the studies is that of mixed levels of prior task and/or team experience. The task and team experience parameters in the framework are based on the assumption that all members of the group have attempted the task the same number of times previously or have all collaborated together the same number of times. This was developed from the card sort study in Chapter 7 where the assumption was true and supported to an extent in the PDA study in Chapter 9. However, Group 2 in the PDA study had had an extra meeting where only two members had turned up – because of the constraints of the framework, this was considered to be a different group and discarded when assessing the experience parameters. Another way of looking at this would be to consider the group as having mixed levels of task and team experience, based upon their attendance.

10.1.3 Future Work

The lightweight validation of the collaborative schemata framework in Chapter 9 suggested two revisions to the framework:

1. Revise the model to include pre- and post- states

   One of the main findings of the validation process was that the framework could benefit from recording the state of a concrete collaborative instance (in terms of its collaborative parameters and its collaborative resources) both at its beginning and at its end. The first part of any future work in this direction would be to perform further validation of the framework incorporating this extended state-transition-state style.

   However, a further development of this would be to identify how particular patterns of activities effect particular changes in state. If it can be established that there are patterns of activity between certain states, this may also help understanding of how high level patterns of collaborative flow occur.

2. Develop a method for more effective capture of the pre-state

   Another major point identified in the validation was the difficulty in establishing the pre-state of a concrete collaborative instance without observing the instance and then making some inferences about the group's collaborative state when they started.

> One way to approach this would be to develop questions to ask the group before they start an observed collaboration, in order to capture the starting state.

Additionally, the wider issue of applying method to the use of the collaborative schemata framework would benefit from further study. This would help to strengthen the framework's use as a GSS design tool.

More work needs to be done on developing the task and team experience parameters so that they can be more easily compared over different types of collaboration. As the framework stands, task and team experience is more easily accrued in, for example, the card sort study than in the PDA study because of the repeated card sorting trials each being considered as distinct completed tasks.

Another area that could be usefully explored in future work is the validation of the framework for parameter settings that were not explored in this thesis. In particular, the thesis focussed on co-located, synchronous meetings; distributed and asynchronous meetings would be much harder to observe, so two areas of validation would be appropriate for these extensions – one to find out the viability of gathering the data required to form a concrete schema and another to determine whether the set of collaborative activities used for co-located, synchronous meetings is still applicable.

Finally, the literature review suggested that groups of more than seven people often work together in different ways to groups of seven or less. This distinction is often labelled as the difference between large and small groups. This thesis has focussed upon collaboration within small groups so further studies would be needed to establish what differences in representation or augmentations would be required to the framework if it were to represent collaboration in large groups. This work may be a natural extension to a study of sub-groups as this is one common way that large groups handle work distribution.

10.2 Taskwork Model

10.2.1 Contribution

The taskwork model was developed from the analysis of a series of group meetings to show a series of states and transitions that the groups used to breakdown a complex, unstructured task into something both achievable and manageable. The model can contribute to the design of new support systems for problem-solving groups because it shows where breakthroughs need to be made for groups to move from one state to another and maintain their progress in breaking down the task complexity.

In a wider context, the development of the model showed that there were points in group meetings where real progress was being made towards the completion of the task, and others where it wasn't. This led to the conceptual analysis of flow, as a means of understanding why progress was not linear.

10.2.2 Limitations

The model is limited because it does not take into account teamwork factors in breaking down the task complexity. However, it can still be used in isolation to focus on the specific act of complex task breakdown. The SYMLOG Interaction Scoring system (Bales and Cohen, 1979) was an effective way of finding the points of 'activity focus' that drove the groups around the model. Its advantage was that analysis messages were formed that captured the perceived mood of the person acting towards both the person/people they were communicating with and the perceived mood towards what they were communicating about. This system allowed the isolation of 'strong' statements about the task, which appeared to be the points at which progress towards the task was made.

10.2.3 Future Work

In the discussion about the collaborative framework one area of future work that was identified was the need to explore how well it could be applied outside the domain of co-located, synchronous collaborative tasks. The taskwork model would also benefit from this consideration. It can be reasoned that asynchronous group work may not allow a task to be broken down with the same pattern of states and transitions, as availability of resources – particularly human resources – may affect what is possible at any given time.

For distributed groups, there may also be issues around communicating the points of 'activity focus' to other group members. These were identified as the triggers for transition between the states in the model, so further work could help to understand whether this is the case and, if so, whether supporting better communication of these triggers would enable distributed groups to perform more comparably to co-located equivalents for problem-solving tasks.

10.3 Conceptual Analysis of Collaborative Flow

10.3.1 Contribution

The conceptual analysis of flow was made in two parts. The first was a reflection on the ideas of individual flow (Csikszentmihalyi, 1996) and group flow in creativity (Sawyer, 2003) and how these related to the observations in the jigsaw and flora and fauna studies. The second was a study into how experience of teamwork and taskwork respectively affected the flow of collaboration.

In addition to investigating the nature of flow, the thesis also identified what it means to have disruptions in collaborative flow and how these occur. In particular, it found that the removal of either shared task or shared team experience from a group led to further disruptions in flow. Later on, it also identified some initial patterns of disruption in groups performing a complex task, showing that factors prior to a meeting (in a series) could lead to either a consistent reduction in disruption, or a series of convergent and divergent actions.

The conceptual analysis of collaborative flow indicated that groups may use a series of repeated activity types in order to work through and complete their tasks. Some of these activity types can be drawn from the taskwork model, but activity types that represent teamwork also need to be considered. Additionally, the way in which group members monitor each other's work was identified as an important component of collaboration. The card sort study also highlighted that collaborating group members often perform individual activities in addition to collaborative ones, both of which are important to the overall collaborative effort.

The conceptual analysis of collaborative flow can contribute to the design of new support systems for problem-solving groups because it gives an enhanced understanding of what factors enable a group to be in collaborative flow and what factors prevent it. There is also some evidence that certain prior factors will cause a particular pattern of flow to occur, but this requires further research.

10.3.2 Limitations

The card sort study showed that although there is evidence of collaborative flow being developed in groups, there are two complex problems that arise in trying to understand the development:

1. The association to taskwork.

   This problem was explored, but at present is a limiting factor on how collaborative flow can be separated from other factors and measured.

2. The transferability of developed teamwork.

   In the card sort study, for this simple task, there was more evidence that an understanding of task was more easily transferred to another group than an understanding of working together was transferred to another task.

10.3.3 Future Work

In the PDA study in Chapter 9, there was some empirical evidence that different patterns of collaborative flow exist within specific collaborative instances. A better understanding of these patterns, and their relationship to the activities in the collaborative schemata framework, could lead to a much stronger presence of collaborative flow in the framework's representation of collaboration.

10.4 Next Steps

From the potential future work identified, this final section considers what may be the most fruitful next steps in strengthening and extending the work presented in this thesis.

The first step in extending this work should be to perform a more systematic validation of the collaborative activity types proposed in this thesis in co-located, synchronous collaborations. The activities were developed from other theories to form part of the framework and the validation so far has shown that they effectively express the chosen collaborations. However, two questions remain unanswered by the validation to date: first, are all the activity types useful and second, is the set complete.

The first question needs to be answered because although the set of activity types was presented as a plausible set of descriptors, not all of them have been necessary to describe collaborative instances presented in this thesis. Similarly, the second question needs to be answered to make sure there are no gaps.

Once the activity types have been more extensively validated, the issue of mixed task/team experience within the group needs to be pursued. The outcome of further studies aimed particularly at this aspect of the framework may result a range of improvements, but it may also require further activities aimed at specifically overcoming the disruptions in flow caused by the mixed experience. It is for this reason that it is suggested to pursue studies validating the original activities first.

The final 'next step' should be to explore the generalisability of the collaborative schemata framework beyond the current use of co-located, synchronous collaborations. This research may well lead to further revisions to the set of activity types, but those modifications would be sounder if the first two 'next steps' were applied first.

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